DOCUMENT RESUME

ED 205 259 PS 011 892

TITLE	Croissance et developpment de l'enfant: 25 ans d'activities internationales coordonnees. Growth and Development of the Child: 25 Years of Internationally Coordinated Activities.
INSTITUTION	International Children's Centre, Paris (France).
PUB DATE	80
NOTE	262p.: A special issue of the "Courrier" dedicated to the XVIth International Congress of Pediatrics, Barcelona.
LANGUAGE	English: French
JOURNAL CIT	Courrier: v30 1980
EDRS PRICE	MF01/PC11 Plus Postage.
DESCRIPTORS	Adolescents: Age Differences: *Behavior Development: Children: Comparative Analysis: Cross Cultural Studies: Foreign Countries: Heredity: Infants: *Intellectual Development: Intelligence Quotient: Longitudinal Studies: *Maturity (Individuals): Measurement Techniques: Motor Development: *Physical Development: Program Descriptions: *Psychological Characteristics: Sex Differences
IDENTIFIERS	Africa: Belgium: England: France: Gesell Developmental Tests: Sweden: Switzerland: Toilet Training

ABSTRACT

This special issue of the "Courrier," a journal for professionals concerned with issues related to the physical and psychological development of children, provides (1) an overview of 25 years of internationally coordinated research, (2) a selection of papers published by the research teams, and (3) a description of the teams and their present status. The origin and international expansion of the program for longitudinal studies is described in the first article. The subsequent 15 articles cover a wide range of topics. Studies concerned with physical development focus on the skeletal maturation of the hand and wrist: growth in the density of normal infants' subcutaneous cellular tissue: age of onset of menarche and associated factors among Parisian girls: clinical transformations of puberty in young girls: international comparisons of infants' physical growth: development and maturation of young children in Dakar: Gessell tests on African children: parent-child correlations for body measurements of children between the ages of 1 month and 7 years: the somatic development of urban, Swedish children: and analysis of the adolescent growth spurt using smoothing spline functions. The one study focused solely on psychological development discusses intellectual development from birth to 18 years of age. Studies covering both psychological and physiological development examine bowel and bladder control during the day and at night in the first 6 years of life: trends in the development of abilities related to somatic growth: individual differences as seen in developmental and intelligence quotient curves from 6 months to 17 years: and a comparison of infant development in five western countries. (Author/RH)

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Croissance et développement de l'enfant

25 ans d'activités internationales coordonnées

Growth and Development of the Child

25 years of Internationally Coordinated Activities

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CENTRE INTERNATIONAL DE L'ENFANCE

COURRIER

INTERNATIONAL CHILDREN'S CENTRE

Numéro spécial du COURRIER à l'occasion du XVI[e] Congrès International de Pédiatrie, Barcelone.
A special issue of the COURRIER dedicated to the XVIth International Congress of Pediatrics, Barcelona.

Sommaire — Contents

I. Twenty-five years of internationally coordinated research: longitudinal studies in growth and development. Introduction and history, by F. Falkner. 3

Vingt-cinq ans de recherche coordonnée internationale. Etudes longitudinales sur la croissance et le développement. Introduction et historique, par F. Falkner. 8

Veinticinco años de investigaciones internacionales coordinadas. Estudios longitudinales sobre el crecimiento y el desarrollo. Introducción y resumen histórico por F. Falkner. 13

II. A selection of especially relevant papers published by the teams.

Une sélection d'articles particulièrement importants publiés par les équipes.

Some international comparisons of physical growth in the two first years of life, by F. Falkner, M. P. Pernot-Roy, H. Habich, J. Senecal and G. Massé. 18

Growing up in five countries: A comparison of data on weaning. Elimination training, age of walking and IQ in relation to social class from European longitudinal studies, by C. Hindley. 28

L'évolution de l'épaisseur du tissu cellulaire sous-cutané chez l'enfant normal de la naissance à 3 ans, par J. Corbier (Bruxelles). 34

Etude longitudinale du développement intellectuel de la naissance à dix-huit ans, par F. de Borggraef-Rauls, C. Emery-Hauzeur, E. A. Sand (Bruxelles). 54

Croissance et maturation de l'enfant à Dakar, par G. Massé (Dakar). 64

Skeletal maturation of the hand and wrist in West Afrikan children, by G. Massé and E. E. Hunt, Jr. (Dakar). 68

Gesell tests on African children, by M. Geber and R. F. A. Dean (Kampala). 79

An analysis of individual patterns of DQ and IQ curves from 6 months to 17 years, by C. B. Hindley and C. F. Owen (London). 87

Parent-child correlations for body measurements of children between the ages one month and seven years, by J. M. Tanner and W. R. Israelson (London). 102

Evolution clinique de la puberté de la fille (Etude longitudinale somatique de 80 adolescentes), par M. P. Roy, M. Sempé, E. Orssaud, G. Pedron (Paris). 112

Age de la marche et facteurs associés étudiés dans un échantillon longitudinal de 296 enfants parisiens, par E. Patois, M. P. Roy, M. Sempé, J. Lellouch (Paris). 119

Trends in development of abilities related to somatic growth, by A. Brucefors, I. Johannesson, P. Karlberg, I. Klackenberg-Larsson, H. Lichtenstein, I. Svenberg (Stockholm). 125

The somatic development of children in a Swedish urban community. A prospective longitudinal study. I. Physical growth from birth to 16 years and longitudinal outcome of the study during the same age period, by P. Karlberg, J. Taranger, I. Engström, J. Karlberg, T. Landström, H. Lichtenstein, B. Lindström, I. Svennberg-Redegren (Stockholm). 129

Longitudinal study of bowel and bladder control by day and at night in the first six years of life. I. Epidemiology and interrelations between bowel and bladder control. II. The role of potty training and the child's initiative, by R. H. Largo and W. Stutzle (Zurich). 153

Analysis of the adolescent growth spurt using smoothing spline functions, by R. A. Largo, Th. Gasser, A. Prader, W. Stuetzle, P. J. Huber (Zurich). 164

III. Description of the teams and their present status.

Description des Equipes et de leurs activités actuelles.

A general picture — Tableau général. 173

Bruxelles; Dakar; Kampala; London; Paris; Stockholm-Göteborg; Zurich; Louisville. 174

IV. Bibliographie et Index - Bibliography and Index. 1951-1980, préparés par J.-P. Deschamps et G. Morel. 213

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Twenty-five years of internationally coordinated research: Longitudinal studies in growth and development

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This publication is dedicated to the fond memory of

Dr. Nathalie P. Masse

by the Coordinated Centre International de l'Enfance Growth Study Teams

The assistance of
John H. Himes, Ph.D.
First Nathalie Masse Fellow is gratefully acknowledged

Introduction and history

Frank FALKNER

In presenting this Introduction, I have drawn heavily on the late Nathalie Masse's "Bilan de Vingt et Un Ans de Recherches Coordonnées" (in Compte Rendu de la XII[e] Réunion des Equipes Chargées des Etudes sur la Croissance et le Développement de l'Enfant Normal, Paris: C.I.E., 1974), and received many helpful suggestions from colleagues involved in the coordinated studies.

Little did one think at Windermere in 1952, during a meeting of the British Paediatric Association, that today there would be grouped eight coordinated international studies on growth and development of children. Professor Robert Debré was present as a distinguished lecturer, and after hearing of a growth study in progress in London, he was interested in extending this work to Paris. Professor Alan Moncrieff, co-instigator of the London study, made a trio with Frank Falkner, and there was born the idea of a second study in Paris to run on exactly parallel lines to the London investigations.

The London study came about as a joint initiative of two institutes of the University of London: Child Health (Professor Moncrieff) and Education (Professor Dorothy Gardner). It was a longitudinal study of growth and development of children.

As a result, in 1953 the author came to Paris on a year's leave of absence at the invitation of Professor Debré and the Executive Board of the Centre International de l'Enfance. The Paris study was set up at the Ecole de Puériculture.

Surprisingly quickly, other international child health centers showed an interest in coordinated longitudinal growth study research and wished to consider the possibility of mimicking the London-Paris coordination with extensions into other countries. At this early stage of discussions, a sense of alarm seized the author. Would he spend the next several years of his academic life travelling widely and setting up coordinated studies globally? The alarm was heightened because he was not at all sure, then, that the bases for such studies were necessarily good or correct ones.

Eventually a group of representatives from centers that wished to participate met after much discussion and formulated "A Common Base-line for Longitudinal Studies on Child Growth" (Falkner, 1954). Extracts from that 25-year-ago publication are interesting and informative:

"It is important to formulate here the following three essential points:

1. It has never been intended that anyone should lay

down what should or should not be studied in the various centres. It is highly desirable that each centre should be directed individually and be free to undertake research in any particular field.

It has, however, been found desirable that all the study centres should, by common accord, adopt **the same research base-line;** this has been possible, and in the future will provide internationally comparable data, the value of which will surpass that of individual studies. This is the sole aim of this publication.

2. It will be of fundamental importance that the staff engaged in these studies should meet regularly (in principle, once a year) in order to compare results, make a critical review of the methods, and update the research in accordance with the age of the children, and with new knowledge.
3. This publication is the first of its kind and is in no way definitive."

This first publication defined the various sectors of research which were proposed to all the Teams cooperating in the project. The following extracts are taken from it:

"The common research base-line is made up of a series of investigations to be made on a sample of children. They may be divided as follows:

I. Social environment.
II. Antenatal period, childbirth, neonatal period and family antecedents.
III. Health status and feeding since the last visit.
IV. Physical status judged on the basis of a clinical examination.
V. Somatic measures, including X-ray examinations.
VI. Psychological development: Tests.
VII. Psychological development: Interrogation of the mother.
VIII. Psychological development: Observations.
IX. Genetic influences.
X. Other somatic research applicable to present problems in growth research."

A working group on child growth studies met in Paris on 4 and 5 October 1954, under the chairmanship of the late Professor M. Lelong. Among other recommendations were:

1. That the coordinated studies to be undertaken by the various countries in London, Paris, Stockholm, Zurich, Brussels, Dakar, and Kampala, should be continued and eventually extended.
2. That each longitudinal study should be made on as homogeneous a sample as possible, taken as randomly as possible among the children of the various cities.
3. That the study Team in charge of this research should include at least a paediatrician, a psychologist, and a social worker.
4. That some analysis of the findings should be begun this year so that they may be discussed at the next meeting.
5. That horizontal surveys should be carried out every five or ten years to check the value of the work undertaken.
6. That the somatic, psychological, and social record-cards drawn up by the working group should be used in all the centres.

On reading what follows in this publication, the progress of the then-small snowball will be gathered. How would it be possible to weld progressively eight separate groups into a state of agreement on principles involved? To think that the various disciplines represented would ever actually agree and plan common veins of investigation? To surmount the language barrier as just one obstacle? How indeed has it been done and is continuing to be done?

The main answer is that information on growth itself in the countries represented is needed badly—hence the constant stimulation. Next, the spirit of competition: Surely it is admirable in a large group to want your Team to have the highest standard. But most of all, because there appeared to have been born a family, and Nathalie Masse became its mother in the best sense of that word.

The family consisted of the Teams carrying out the work. We have grown to know each other well and to look forward eagerly to our family reunions. It would be a dull family indeed that did not have fights inside it—ours has had them and as with all the **best** families. When they are quickly over, friendships are better and a still higher standard has emerged.

Brief Account of Subsequent Stages and Orientation

Coordinators were appointed from among the Team leaders for each important sector of research at various times: C. Hindley (psychology); P. Karlberg (analysis); J. M. Tanner (somatic growth). The overall coordination was undertaken by the author, in collaboration with the C.I.E. First yearly, then two-yearly, meetings were held in turn in the different European research centres. In reviewing the reports of these various meetings, the main events which have marked the development of the Teams and their work show. Highlights are noted.

After **1954: Paris** — When the first working group met, as we have seen, the next meeting was:

1955: Stockholm — The number of research workers who met was still small, but all the coordinated Teams were present. For the first time, P. Karlberg raised the problem of **statistical analysis** of the results, and suggested that it would be timely to prepare coded record-cards which could be analyzed by computer. In the months that followed, a considerable amount of work was carried out to standardize and code the record-cards.

1956: London — M. Graffar reported on the preliminary findings of a numerical scale of **social classification** which took a number of factors into account; this scale is now widely used throughout the world.

1958: Brussels — Several facts stand out from this meeting:

1. The first study of the **comparative results** of several Teams was published.
2. A thorough discussion was held on the methods for estimating *bone maturation*.
   The technique of the Tanner and Whitehouse method was published by the C.I.E. in 1962.
3. J. Sénécal and M. Géber reported on the **advanced development** of children in Senegal and Uganda during the first few months of life.
4. Finally, for the first time, research workers belonging to other centers, but having the same interests as ourselves, took part in the meeting and reported on their findings. They were to become a network of **"friends"** closely linked to our research group.

1960: Zurich — The meeting immediately followed an international seminar on The Growth of the Normal Child during the First Three Years of Life. It was outstanding for the contributions of R.F.A. Dean on the role of **nutrition.** Unfortunately, the Kampala study was interrupted by the death of our colleague Dean; its psychological aspects were subsequently presented from time to time by M. Géber.

1962: London — The Teams were faced with the problems of **statistical methodology** applied to the longitudinal studies.

1964: Paris — Preparation of protocols for observation of **puberty** in girls and boys.

1966: Stockholm — Longitudinal data on **psychological development** were reported by the Stockholm, London, and Brussels Teams.

1968: Brussels — Discussion covered, among other things, the influence of **social factors.**

1970: Davos — For the first time, the London, Zurich, and Paris Teams reported on an analysis of **pathological growth.**

1972: London — The discussion centered on **puberty, bone maturation** and **statistical methodology.**

1974: Paris — The progress of the studies and age of the children in the samples were reflected by examples of presentations being:

C. Hindley, on the development of ability related to parameters from 6 months to 17 years; M. P. Roy, E. A. Sand, E. A. Werder, and A. F. Roche, separately, on growth at adolescence, including adult height prediction.

It was at the conclusion of this meeting that C. Hindley presented Future Plans, and Nathalie Masse her 21 years of Coordinated Research referred to earlier.

1976: Rennes — Both the psychological and somatic Team members, together with the "friends", presented findings that especially involved the longitudinal aspects of the studies. There was also appropriate time given to discussions of somewhat sophisticated mathematical approaches to data analysis.

1978: Göteborg — The main theme of this meeting was the future. That is to say, a summation of what the Teams had achieved to date, what further work could be done with the data already collected, and what future work could be done by the collaborative Teams.

Each of these meetings naturally dealt with all the problems included in the research programme, but we considered it of interest to show how particular questions and orientations, which later assumed great importance, came up spontaneously.

Evaluation and Progress

The detailed accounts of the status of each Team's data bank and situation will be found in another section of this issue.

The following is a general overview.

All the Teams which started in 1953 to 1955 are still present in the group. The Kampala Team's regular work was interrupted (as was said earlier) sadly by the death of R. F. A. Dean. M. Géber returned on several occasions to see certain children in connection with the psychological aspects. The Dakar Team stopped data collection after six years. Most of the children were found again at the age of 12 years, and are now being followed up regularly.

Sample size differed quite considerably from one centre to another. All the Teams were able to follow the base-line regarding somatic growth and carry out assessment of the socioeconomic environment. The psychological part of the studies was interrupted at the ages of six years in Dakar and Paris, and was only partially studied in Zurich. Several Teams broadened the protocol considerably, beyond the base-line. This was particularly the case with the Stockholm Team for psychology, the London Team for ossification, and the Zurich and Paris Teams for pathological influences on growth and development.

Some Reflections

The question has been asked what the coordinated studies were able to do and could not do. They were limited, clearly, by finance and manpower. This determined that sample sizes could not be large, that the amount of detailed information which could be collected was restricted, particularly regarding the psychological investigations, and that analysis of the rich accumulation of data was limited. Regarding the samples themselves, as with all longitudinal studies, the need for long-term continuing cooperation results in selective loss from samples, and it must be said, therefore, that these cannot be said to be random, stratified, nor really appropriate for much normative data. It also must be said, however, that results have been, and still are, used in some countries (for example, Belgium) if only because no other data are available.

It could be said that in the early 1950s, we should have formulated a number of clear hypotheses for testing. Our view is, though, that perhaps we were wise not to have done so. One example: If we had planned very carefully and hypothesized restrictively, there was, at that time, almost only paper-and-pencil methods of

analysis. The progress of technology and biometric skills enabled us, as we progressed, to master sets of data that would have been unthinkable originally. Indeed, one of the spinoffs has been, particularly of late, that we have first interested mathematical statisticians in our problems—a feat in itself—and then learnt much from them.

Further, after analysis of the data over the years, hypotheses have been continually suggested. This stimulates the creation of future, more limited longitudinal and semi-longitudinal studies to test them.

At this point it has to be said that relating somatic to psychological data in our studies has not been carried out enough, thus perpetuating a seemingly common deficit in all such multi-disciplinary growth and development studies.

Returning to the inherent limitations of gleaning information from the studies, it would be foolish to reject the data on purist grounds. The great advantage of longitudinal study is that observed changes in individuals and groups can only be due to real change, other than through measurement error. There are, in fact, very few scientific studies on children—somatic, psychological, biomedical—where samples can be said to be unbiased and from a wide population.

Because of the nature of the investigations and studies, there is no need to be defensive about, for example, sampling, since whatever developmental changes have been, or will be, found, are more than likely to be found in the general population. The fact that the Teams have several differing samples allows of some testing for replication of findings, and, as mentioned earlier, stimulates further testing of replication in other places and at other times.

Positively, a key point must be made; it is simple, yet few take it seriously: Growth and development is a process which occurs in individuals, and only in individuals. Hindley and Owen (1979) bring this out succinctly stating that so-called developmental data consisting of group means at different ages may well not portray the form of developmental change occurring in anyone. While it is clearly of value to know how children in general change with age, shown by such grouped data, it is essential to study, too, the growth and developmental changes in each child and to examine individual differences in developmental trends. These things the Teams can do.

It should be mentioned that there is a worldwide shortage of long-term longitudinal data. They exist in a few studies mainly in the United States. The Teams' work has provided an important addition.

We should address the area of a number of indirect results and contributions from the studies.

1. Application to Social Pediatrics and Public Health

Although the limitations have been discussed, the studies have had an impact on preventive and social pediatrics. In several countries, they have stimulated the establishment of references, charts, and graphs used by pediatric, maternal and child health, and school health services. Some of the members of the Teams have cooperated with the World Health Organization in the establishment of international reference charts and contributed to the developing trend towards the use of the growth characteristics of children as indicators of the health and nutrition of a population.

2. Application to Clinical Medicine

The development of an accurate method for analyzing growth and maturation has made it possible to refine pediatric symptomatology and to describe the related abnormalities peculiar to various endocrine and metabolic diseases.

3. Application to Teaching

The data collected by the various Teams are widely used for the teaching of students and future specialists. This is facilitated by the fact that the centers are almost all associated with university departments of pediatrics. These data are also widely used by the C.I.E. teaching professionals.

4. Exchange of Experience with the Group of Friends

The participation of other research workers, or "friends", has been, over the years, a very profound source of stimulation and mutual information.

What of the Future?

Most of the Teams have adequate data systematically collected by experienced investigators and containing large areas that have never been analyzed. Particularly in the psychological part of the studies is this so; simple examples being children's creativity, interests, attitudes, values, and educational attainment, all over time, and the way these are related to each other. The relationships of these and other psychological factors and states to somatic growth remain unanalyzed, and to achieve such investigation would not only remove a justified criticism of multi-disciplinary longitudinal studies, but could reveal a horn of plenty for future contributory work.

One must not forget the unique data that exist on individuals, and when they have reached maturity, those data still exist. Thus, follow-up at certain stages of adult life of individuals would produce further unique data and answer some human biological questions that can only be answered by such an approach. The scope, here too, for further comparative study between the centers would be very large.

These general considerations imply that it would be highly beneficial for contact never to be lost with the cohorts and for the Teams to continue meeting and maintaining a coordinated effort.

It has to be faced, of course, that any continuation depends on financial and other support in hard times. This means individual and collective efforts will be needed towards these ends, and perhaps giving a priority towards investigation that will hopefully lead to bet-

ter health and happiness will be the route most likely to succeed.

Other More Intangible Benefits from the Studies:

All Team members of varying seniority stress that to have become acquainted with the views and experience of others doing closely related work has been invaluable, not only resulting in higher standards of their own work, but from an educational aspect. Team members have also learnt with profit a great deal about other disciplines quite different from their own. Just one general example is worthwhile giving. The expertise of the Brussels Team on the study of social class variables has taught very many of us, and provided us with more effective ways of assessing them than we would otherwise have had.

The collaboration has often opened eyes to differences in, for example, mode of life, child rearing, in other countries, and the relationships of these factors to the growth and development of individuals.

In all modesty, the continued collaboration and coordination of the Teams has encouraged and stimulated the study of growth and development in many different countries, including those in the developing world, and thus contributed to the betterment of child health.

A final notable benefit has been the build-up, over the years, of something most intangible: scientific and personal friendships. The author is particularly grateful for these.

Vingt-cinq ans de recherche coordonnée internationale
Etudes longitudinales sur la croissance et le développement

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Cette publication est affectueusement dédiée à la mémoire du

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par les Equipes d'Etudes sur la Croissance du Centre International de l'Enfance

L'auteur remercie pour son aide
John H. Himes, Ph.D.
Premier boursier du Mémorial Nathalie Masse

Introduction et historique

Frank FALKNER

Pour écrire cette Introduction, l'auteur a largement puisé dans l'ouvrage de Nathalie Masse «Bilan de Vingt et Un ans de Recherches Coordonnées» (Compte Rendu de la XII[e] Réunion des Equipes Chargées des Etudes sur la Croissance et le Développement de l'Enfant Normal, Paris: C.I.E., 1974). J'ai aussi reçu beaucoup d'utiles conseils de collègues engagés dans la Recherche Coordonnée.

On ne se doutait guère, lors d'une réunion de l'Association Britannique de Pédiatrie à Windermere en 1952, que huit Groupes d'Etude Internationale Coordonnée sur la Croissance et le Développement de l'Enfant seraient rassemblés aujourd'hui. Le Professeur Robert Debré y assistait comme conférencier éminent et, ayant eu connaissance de l'Etude sur la Croissance qui se poursuivait à Londres, souhaita étendre ce travail à Paris. Le Professeur Moncrieff, l'un des initiateurs de l'Etude de Londres, forma un trio — Debré, Moncrieff, Frank Falkner — et ainsi naquit l'idée d'une seconde Etude, identique, menée à Paris parallèlement aux recherches de Londres.

L'Etude de Londres était le fruit de deux Instituts de l'Université de Londres: Santé de l'Enfant (Professeur Moncrieff) et Education (Professeur Dorothy Gardner). C'était une étude longitudinale sur la croissance et le développement de l'enfant.

En conséquence, invité en 1953 par le Professeur Debré et le Conseil d'Administration du Centre International de l'Enfance, l'auteur vint à Paris en congé pour un an. L'étude de Paris fut installée à l'Ecole de Puériculture.

Avec une surprenante rapidité, d'autres centres internationaux de santé de l'enfant manifestèrent leur intérêt pour l'étude longitudinale coordonnée de la croissance et envisagèrent la possibilité d'imiter la coordination Paris-Londres et de l'implanter dans d'autres pays. A ce premier stade, l'auteur fut pris de panique: les prochaines années de sa vie professionnelle se passeraient-elles à parcourir le monde pour y démarrer des Etudes coordonnées? Son inquiétude s'aggravait du fait qu'il n'était nullement certain, à l'époque, que les bases de ces études étaient nécessairement solides et correctes.

Par la suite, des délégués de centres désireux de s'intégrer à ces travaux se réunirent et, après de longues discussions, rédigèrent la «Base commune de recherche pour les Etudes Longitudinales sur la Crois-

sance de l'Enfant» (Falkner, 1954). Des extraits de ce texte vieux de 25 ans sont intéressants et instructifs.

«Il importe de formuler ici les trois points essentiels suivants:

1. Il n'a jamais été question que quiconque prescrive ce qui devrait ou ne devrait pas être exploré dans les divers centres. Il est hautement souhaitable que chacun dirige personnellement son équipe et puisse poursuivre des recherches dans tel ou tel domaine particulier.
   Il est apparu cependant souhaitable que dans tous les centres d'études soit adoptée, d'un commun accord, une **même base de recherches**; cela a été possible et procurera dans l'avenir des données comparatives internationales dont la valeur surpassera celle des études individuelles. C'est là le seul but de cette publication.
2. Il sera fondamental que le personnel engagé dans ces études se réunisse de façon régulière (en principe, une fois par an) afin de comparer les résultats, critiquer les méthodes et mettre à jour les recherches en fonction de l'âge des enfants et des connaissances nouvelles.
3. La présente publication est la première de ce genre et n'est en rien définitive.»

Cette première publication définissait les divers secteurs de recherche proposés à l'ensemble des Equipes intéressées par ce projet. En voici quelques extraits:

«La base commune de recherche se compose d'une série d'explorations à pratiquer sur un échantillon d'enfants. On peut les répartir comme suit:

I. Milieu social.
II. Période anténatale, accouchement, période néonatale et antécédents familiaux.
III. Etat de santé et alimentation depuis la dernière visite.
IV. Etat physique apprécié par l'examen clinique.
V. Mesures somatiques incluant des examens radiologiques.
VI. Développement psychologique: tests.
VII. Développement psychologique: interrogatoire de la mère.
VIII. Développement psychologique: observations.
IX. Influences génétiques.
X. Recherches somatiques et questions actuelles concernant la recherche sur la croissance.»

Un groupe de travail consacré aux études sur la croissance de l'enfant s'est réuni à Paris, les 4/5 octobre 1954, sous la présidence du regretté Professeur M. Lelong. Parmi ses recommandations, citons:

«Il est recommandé que:

1. les études à entreprendre par les divers pays, à Londres, Paris, Stockholm, Zurich, Bruxelles, Dakar et Kampala, sur la croissance de l'enfant, soient poursuivies et éventuellement élargies;
2. chaque étude longitudinale soit faite sur un échantillon aussi homogène que possible, pris au hasard parmi les enfants des divers pays;
3. l'Equipe de travail chargée de ces études comprenne au minimum un pédiatre, un psychologue et un(e) assistant(e) social(e);
4. un minimum de dépouillement des résultats commence au cours de l'année, afin que ceux-ci puissent être examinés lors de la prochaine réunion;
5. des enquêtes horizontales soient pratiquées tous les 5 ou 10 ans pour vérifier la valeur du travail effectué;
6. le type de fiches établi par le Groupe de Travail soit utilisé par tous les centres.»

En lisant la suite, on jugera des progrès accomplis par le petit noyau initial. Comment amener progressivement huit groupes distincts à se mettre d'accord sur les principes en cause? Comment imaginer que les diverses disciplines représentées parviendraient jamais à s'entendre et à préparer des voies communes d'exploration? La barrière linguistique était à elle seule un obstacle. Comment a-t-on pu le faire? Comment continue-t-on à le faire aujourd'hui?

C'est d'abord grâce à la stimulation constante provoquée dans les pays représentés par un grand besoin d'informations sur la croissance elle-même et, ensuite, grâce à l'esprit de compétition. Il est excellent, au sein d'un large groupe, de souhaiter la supériorité de sa propre Equipe, mais ce qui compte avant tout, c'est qu'une famille semble être née, famille dont Nathalie Masse est devenue la mère au meilleur sens du terme. Les membres de cette famille sont les Equipes d'Etudes. Nous nous sommes peu à peu mieux connus, nous réjouissant à l'avance de nos réunions familiales. Sans luttes intestines, une famille serait bien insipide. La nôtre a connu les siennes comme les meilleures familles. Rapidement apaisées, elles ont renforcé les amitiés et amélioré la qualité du travail.

Aperçu des étapes successives et orientations ultérieures

Des coordonnateurs ont été désignés à plusieurs reprises parmi les Directeurs d'équipe dans chaque domaine important de recherche. C. Hindley (psychologie); P. Karlberg (analyse); J. M. Tanner (croissance somatique). L'auteur s'est chargé de la coordination d'ensemble, en collaboration avec le C.I.E. Des réunions ont eu lieu chaque année, puis un an sur deux, dans les divers centres de recherche d'Europe. L'examen des comptes rendus de ces réunions révèle les faits saillants qui ont jalonné les progrès des équipes et l'avancement de leur travail.

On notera les étapes suivantes:

Après **1954, Paris** — époque où se rencontra le premier groupe de travail, se sont succédé:

1955: Stockholm — Les chercheurs étaient encore peu nombreux mais toutes les équipes coordonnées étaient présentes. C'est alors que P. Karlberg a soulevé pour la première fois la question de l'**analyse statistique** des résultats et émis l'idée que le moment était venu d'établir des fiches d'observation codées susceptibles d'être analysées sur ordinateur. Au cours des mois suivants, un travail considérable de codification et de normalisation des fiches fut réalisé.

1956: Londres — M. Graffar a rendu compte des résultats préliminaires d'une échelle numérique de **classification sociale**, qui tenait compte d'un grand nombre de facteurs; échelle dont l'usage s'est généralisé dans le monde entier.

1958: Bruxelles — Plusieurs faits ont marqué cette réunion:

1. Publication des premiers **résultats comparés** de plusieurs Equipes.
2. Discussion approfondie sur les méthodes d'évaluation de la **maturation osseuse**.
   La technique de la méthode de Tanner et Whitehouse a été publiée par le C.E.I. en 1962.
3. Rapport de J. Sénécal et M. Gèber sur la **précocité du développement** des enfants au Sénégal et en Ouganda durant les premiers mois de la vie.
4. Enfin, et pour la première fois, des chercheurs, venant de Centres différents mais intéressés par les mêmes questions que nous, ont pris part à la réunion et ont rendu compte de leurs expériences. Un réseau d'«**amis**» étroitement liés à notre groupe s'est ainsi formé.

1960: Zurich — Tenue immédiatement après un Séminaire International sur la Croissance de l'Enfant normal au cours des Trois premières Années, cette réunion a été marquée par les communications de R. F. A. Dean sur le rôle de la **nutrition.** Malheureusement, l'étude de Kampala a été interrompue par la mort de notre collègue Dean. Par la suite, M. Geber a, à plusieurs reprises, présenté les aspects psychologiques de cette étude.

1962: Londres — Les Equipes ont abordé la question de la **méthode statistique** appliquée aux études longitudinales.

1964: Paris — Etablissement des protocoles pour l'observation de la **puberté** chez les filles et les garçons.

1966: Stockholm — Données longitudinales sur le **développement psychologique,** présentées par les Equipes de Stockholm, Londres et Bruxelles.

1968: Bruxelles — Le débat a porté, entre autres, sur l'influence des **facteurs sociaux.**

1970: Davos — Pour la première fois, les Equipes de Londres, Zurich et Paris ont rendu compte d'une analyse sur la **croissance pathologique.**

1972: Londres — Débat axé sur la **puberté,** la **maturation osseuse** et la **méthodologie statistique.**

1974: Paris — L'avancement des études sur l'âge des enfants dans les échantillons s'est retrouvé dans certaines communications — notamment celle de C. Hindley sur le développement des aptitudes en fonction de paramètres, de 6 mois à 17 ans, et celle de M. P. Roy, E. A. Sand, E. A. Werder et A. F. Roche, respectivement, sur la croissance au moment de l'adolescence, notamment sur la prévision de la taille à l'âge adulte.

A l'issue de cette réunion, C. Hindley a présenté les Plans d'avenir et Nathalie Masse son rapport sur Vingt et Un Ans de Recherche Coordonnée, dont il a été question plus haut.

1976: Rennes — L'Equipe de psychologie et l'Equipe d'études somatiques ont présenté, avec les «amis», des expériences portant plus particulièrement sur les aspects longitudinaux des études. Le temps nécessaire a été consacré à l'examen de certains aspects mathématiques quelque peu complexes, relatifs à l'analyse des données.

1978: Göteborg — Le thème principal de cette rencontre a été l'avenir. C'est-à-dire le résumé du travail des Equipes à l'époque, l'examen du travail à poursuivre sur les données déjà recueillies et enfin, l'activité future à attendre de la collaboration des Equipes.

Chacune de ces réunions a, naturellement, traité de toutes les questions du programme de recherches mais l'auteur a jugé intéressant de montrer comment s'étaient présentées spontanément des questions et des orientations qui devaient assumer ultérieurement une importance majeure.

Bilan et état des travaux

Les comptes rendus détaillés de la situation actuelle des banques de données de chacune des équipes sont présentés plus loin dans ce numéro.

On en trouvera ci-après un aperçu général.

Toutes les Equipes constituées entre 1953 et 1955 adhèrent encore au groupe. Comme il a été dit, le travail entrepris par l'Equipe de Kampala a été, hélas, interrompu par la mort de R. F. A. Dean. M. Geber est retournée plusieurs fois sur place pour revoir certains enfants du point de vue psychologique. L'Equipe de Dakar a cessé de recueillir des données au bout de 6 ans, mais la plupart des enfants ont été retrouvés à 12 ans et sont maintenant suivis régulièrement.

Les dimensions des échantillons ont varié considérablement d'un centre à l'autre. Toutes les Equipes ont pu suivre les directives sur la croissance somatique et effectuer des observations sur le milieu socio-économique. L'élément psychologique des enquêtes a cessé à l'âge de 6 ans pour Dakar et Paris; à Zurich, il n'a été que partiellement étudié. Plusieurs Equipes sont allées bien au-delà de ce qui était prévu par le protocole. En particulier, l'Equipe de Stockholm en matière de psychologie, l'Equipe de Londres en matière d'ossification et les Equipes de Zurich et de Paris en matière d'influences pathologiques sur la croissance et le développement.

Quelques réflexions

On s'est demandé ce que les enquêtes coordonnées ont été en mesure de faire et ce qu'elles n'ont pas pu faire effectivement. Elles étaient bien évidemment limitées par leurs ressources en argent et en personnel. En conséquence, les échantillons ont été de dimensions réduites et les données détaillées recueillies n'ont atteint qu'un volume restreint, en particulier concernant les explorations psychologiques; en outre, l'analyse du stock important de données accumulées a été limitée. Quant aux échantillons proprement dits, étant donné que toute étude longitudinale exige une coopération suivie de longue durée et entraîne une perte sélective d'échantillons, il faut bien dire que l'on ne peut préten-

dre qu'ils sont choisis au hasard, stratifiés ou vraiment propres à fournir beaucoup de données normatives. Il n'en reste pas moins, il faut le dire, que les résultats ont été, et sont encore, utilisés dans certains pays (la Belgique, par ex.), peut-être faute d'autres données disponibles.

On pourrait nous objecter que nous aurions dû, dès le début des années cinquante, formuler clairement un certain nombre d'hypothèses à vérifier. Nous pensons cependant avoir bien fait de nous en abstenir. Pour ne citer qu'un exemple: à supposer que nous ayions formulé nos programmes avec le plus grand soin et des hypothèses volontairement restrictives, nous n'aurions disposé à l'époque que de méthodes primitives d'analyse. A mesure que nous avancions, les progrès de la technique et de la biométrie nous ont permis de traiter des séries de données impensables à l'origine. En fait une des retombées récentes de ces progrès fait que les spécialistes de la statistique mathématique se sont intéressés à nos problèmes (un exploit en soi!) et que par la suite nous avons beaucoup appris à leur contact.

Avec le temps, en outre, l'analyse des données n'a cessé de susciter des hypothèses nouvelles suscitant par la suite des études longitudinales ou semi-longitudinales destinées à vérifier ces hypothèses.

A ce stade, il faut reconnaître que dans nos études les données somatiques n'ont pas été suffisamment liées aux données psychologiques et que s'est ainsi perpétuée une lacune qui paraît commune à toutes les études pluri-disciplinaires sur la croissance et le développement.

Pour en revenir aux limites inhérentes au système qui consiste à utiliser des informations glanées dans les études, il serait déraisonnable de rejeter ces données par purisme. L'avantage primordial de l'étude longitudinale tient à ce que les modifications observées chez les individus ou les groupes ne peuvent provenir que de changements réels et non d'erreurs de mesure. En fait, très rares sont les études scientifiques sur les enfants, qu'elles soient somatiques, psychologiques ou biomédicales, dont les échantillons puissent être considérés comme impartiaux et prélevés sur une population étendue.

La nature même des explorations et des études nous évite d'être sur la défensive, par exemple en matière d'échantillonnage, puisque les modifications du développement, passées ou futures, se retrouveront plus que probablement dans l'ensemble de la population. Du fait que les Equipes travaillent sur des échantillons différents, il est possible de faire des contre-épreuves et ceci, comme il a été dit plus haut, incite à procéder à de nouvelles contre-épreuves ailleurs et ultérieurement. En tout cas, il faut insister sur un fait crucial, qui est simple mais rarement pris au sérieux: la croissance et le développement sont des processus qui se manifestent chez l'individu et chez l'individu seulement. Hindley et Owen (1979) l'indiquent succinctement, affirmant qu'il se peut fort bien que les prétendues données sur le développement établies à partir des moyennes d'un groupe à différents âges n'illustrent les modifications du développement d'aucun individu en particulier. S'il importe manifestement de savoir comment les enfants, en général, changent avec l'âge (changements mis en évidence par ces données de groupe), il convient également d'étudier les changements dans la croissance et le développement de chaque enfant ainsi que les différences individuelles dans les tendances du développement. Les Equipes sont en mesure de faire ce travail.

Il convient de mentionner la carence mondiale de données longitudinales à long terme. On en trouve dans quelques études, particulièrement aux Etats-Unis. Le travail des Equipes y a apporté un complément important.

Il faudrait parler maintenant de certains résultats et apports indirects qui découlent des travaux des Equipes.

1. Application à la pédiatrie sociale et à la santé publique

Bien que critiquées pour leur manque d'étendue, les études ont influencé la pédiatrie préventive et sociale, poussant plusieurs pays à établir des références, tableaux ou graphiques utilisés par les services de pédiatrie, de santé de l'enfant et d'hygiène scolaire. Certains membres des Equipes ont collaboré avec l'OMS pour établir des tables internationales de référence et ont ainsi contribué à la tendance actuelle qui utilise les caractéristiques de croissance des enfants comme indicateurs de l'état sanitaire et nutritionnel des populations.

2. Application à la médecine clinique

L'apparition d'une méthode exacte d'analyse de la croissance et de la maturation a permis d'approfondir la symptomatologie pédiatrique et de décrire les anomalies propres aux diverses maladies des glandes endocrines ou du métabolisme.

3. Application à l'enseignement

L'enseignement aux étudiants et aux futurs spécialistes utilise largement les données recueillies par les Equipes; ceci est d'autant plus facile que les Centres sont presque toujours rattachés aux Départements de pédiatrie des universités. Ces données sont aussi abondamment utilisées par les enseignants du C.I.E.

4. Echange d'expériences avec le groupe des «amis»

Au fil des années, la collaboration d'autres chercheurs ou «amis» a été un stimulant et une source appréciable d'informations réciproques.

Que penser de l'avenir?

La plupart des Equipes possèdent des stocks de données valables, recueillies par des chercheurs expérimentés mais dont des secteurs importants n'ont jamais été analysés, en particulier en ce qui concerne la partie

«psychologie» des études, par exemple la créativité, les intérêts, le comportement, les valeurs, les résultats scolaires, le tout aussi bien dans le temps que dans leurs inter-actions. On n'a pas encore analysé les rapports de ces facteurs, ou d'autres facteurs et états psychologiques, avec la croissance somatique. Cette exploration permettrait non seulement d'éliminer une critique justifiée à l'endroit des enquêtes longitudinales pluridisciplinaires, mais encore de faire surgir une abondance de travaux importants dans l'avenir.

Il ne faut pas oublier les données spécifiques concernant chaque individu, lesquelles subsistent lorsque ceux-ci ont atteint leur maturité. Suivre les sujets à certains stades de leur vie adulte fournirait d'autres données spécifiques et répondrait à certaines questions de biologie humaine que seule une telle approche peut résoudre. Ici aussi, le champ des enquêtes comparatives inter-centres serait très vaste.

Il ressort de ces considérations générales qu'il serait hautement profitable que les Equipes ne perdent jamais le contact avec les cohortes et continuent de se réunir pour poursuivre des travaux coordonnés.

La réalisation de ce travail dépend, il faut le dire, des appuis financiers et autres en des moments difficiles. Des efforts tant personnels que collectifs seront donc nécessaires dans ce sens. La meilleure voie pour y parvenir sera, peut-être, de donner la priorité à la recherche, dont on peut espérer qu'elle aboutira à l'amélioration de la santé et du bonheur des hommes.

Avantages plus difficiles à mesurer découlant des Etudes

Les membres des Equipes, à tous les degrés, s'accordent à dire combien leur est précieuse la connaissance des opinions et des expériences d'autres chercheurs dans des domaines voisins des leurs; elle leur permet d'améliorer non seulement la qualité de leur travail mais de parfaire leur propre formation. Les membres des Equipes se sont initiés avec profit à des disciplines nouvelles très différentes des leurs. Un cas mérite d'être relaté: l'expérience acquise par l'Equipe de Bruxelles dans l'enquête sur les paramètres des classes sociales a enseigné à nombre d'entre nous des méthodes d'évaluation plus efficaces que nous n'aurions jamais connues autrement.

Cette collaboration a souvent ouvert les yeux sur des différences — manière de vivre, d'élever les enfants — dans d'autres pays et sur les rapports entre ces facteurs et la croissance et le développement des individus.

En toute modestie, on peut dire que la collaboration et la coordination permanentes des Equipes ont encouragé et stimulé l'étude de la croissance et du développement dans beaucoup de pays, notamment dans les pays en développement, et qu'elles ont ainsi contribué à l'amélioration de la santé de l'enfance.

Il faut parler enfin d'un avantage considérable: l'élaboration, au cours des années, d'un bienfait intangible, les amitiés sur le plan scientifique et sur le plan personnel. Pour sa part, l'auteur tient ces amitiés pour particulièrement précieuses.

Veinticinco años de investigaciones internacionales coordinadas
Estudios longitudinales sobre el crecimiento y el desarrollo

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Esta publicación está afectuosamente dedicada a la memoria de la

Dra. Nathalie P. Masse

por los Equipos de Estudios sobre el Crecimiento del Centro Internacional de la Infancia

Los redactores agradecen la ayuda
del **Sr. John H. Himes, Ph.D.**
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Introducción y resumen histórico

por Frank FALKNER

Con el fin de escribir la presente introducción, el autor ha consultado ampliamente la obra de Nathalie Masse «Bilan de Vingt et Un ans de Recherches Coordonnées» (Compte Rendu de la XII[e] Réunion des Equipes Chargées des Etudes sur la Croissance et le Développement de l'Enfant Normal, Paris: C.I.E., 1974); ha recibido asimismo múltiples y útiles consejos de Colegas que participan en las Investigaciones Coordinadas.

No se sospechaba siquiera, en 1952, durante la reunión de la Asociación Británica de Pediatría, realizada en Windermere, que existirían hoy dia 8 grupos internacionales de investigaciones coordinadas acerca del Crecimiento y Desarrollo infantiles. El Profesor Robert Debré, que asistía a la reunión como conferenciante eminente, habiéndose enterado de los estudios sobre el crecimiento que se realizaban en Londres, anheló extender dicho trabajo hacia París. El Profesor Moncrieff, uno de los iniciadores de los Estudios londinenses, organizo un trío: Debré, Moncrieff, Frank Falkner; así fue como nació la idea de un segundo Estudio, idéntico al primero, realizado en París en forma paralela al de Londres.

El Estudio de Londres era el fruto de la iniciativa conjunta de dos Institutos de la Universidad de Londres: el de Salud Infantil (Profesor Moncrieff) y el de Educación (Profesor Dorothy Gardner). Se trataba de un Estudio de tipo longitudinal sobre el crecimiento y el desarrollo infantiles.

En consecuencia, en 1953, invitado por el Profesor Debré y por el Consejo de Administración del Centro Internacional de la Infancia, el autor se trasladó a París haciendo uso de una licencia de un año. El Estudio fue organizado en la Escuela de Puericultura.

Con sorprendente rapidez, otros centros internacionales de salud infantil manifestaron su interés por este estudio longitudinal coordinado del crecimiento, considerando la posibilidad de imitar la coordinación de París y Londres para realizarla en otros países. En esos momentos el autor fue preso del pánico: ¿Estarían destinados los próximos años de su vida profesional a recorrer el mundo poniendo en marcha Centros de Estudios Coordinados? Su inquietud aumentó debido a que, en esa época, era muy incierto que las bases que sostenían dichos estudios fuesen necesariamente sólidas y correctas.

Posteriormente, delegados de Centros interesados en integrarse al trabajo se reunieron y redactaron, después de largas discusiones, una «Base Común de Investigación para los Estudios Longitudinales sobre el Crecimiento Infantil» (Falkner, 1954). Algunos extractos de este texto, viejo ya de 25 años, son interesantes e instructivos:

«Es importante formular aquí los siguientes tres puntos esenciales:

1. No se trata de que alguien prescriba qué es lo que puede ser o no ser investigado en los diversos Centros. Es en alto grado deseable que cada cual dirija personalmente su équipo y realice investigaciones en éste o en aquel dominio particular. Pero es también deseable que todos los Centros de Estudios adopten, en común acuerdo, **una misma base de investigaciones.** Esto es posible y podrá procurar, en lo porvenir datos comparativos internacionales de valor superior a aquellos obtenidos mediante estudios individuales. Este es, precisamente, el objetivo de la presente publicación.
2. Es fundamental que el personal comprometido con estos estudios se reúna de manera regular (en principio, una vez al año) con el fin de comparar los resultados, criticar los métodos y poner al día el trabajo en función de la edad de los niños y de los nuevos conocimientos.
3. La presente publicación es sólo la primera en su género: no tiene nada de definitivo.»

Esta primera publicación definía los diferentes sectores de investigación propuestos a los Equipos interesados en el proyecto. He aquí algunos extractos de estos puntos:

«La base común de la investigación se compone de una serie de prospecciones a efectuar sobre una muestra de niños que pueden repartirse de la siguiente manera:

I. Medio Social.
II. Período pre-natal, parto, período neo-natal, y antecedentes familiares.
III. Estado de salud y alimentación a partir de la última visita.
IV. Estado físico apreciado por el examen clínico.
V. Medidas somáticas, incluyendo exámenes radiológicos.
VI. Desarrollo psicológico: tests.
VII. Desarrollo psicológico: interrogatorio de la madre.
VIII. Desarrollo psicológico: observaciones.
IX. Influencias genéticas.
X. Investigaciones somáticas y cuestiones actuales en relación con la investigación sobre el crecimiento.»

Un grupo de trabajo dedicado a los estudios sobre el crecimiento del niño se reunió en París entre el 4 y el 5 de octubre de 1954, bajo la presidencia del recordado Profesor M. Lelong. Destacamos entre sus recomendaciones:

1. Los estudios a realizar por los distintos países en Londres, París, Estocolmo, Zurich, Bruselas, Dakar y Kampala sobre el crecimiento infantil deberían ser proseguidos y, eventualmente, ampliados.
2. Cada estudio longitudinal debería realizarse sobre una muestra lo más homogénea posible, tomada al azar entre los niños de los distintos países.
3. El equipo de trabajo encargado de estos estudios necesita de un mínimo de un pediátra, un psicólogo y un(a) asistente social.
4. Una mínima clasificación de los resultados debería comenzar ya en el curso del año, a fin de que puedan ser examinados en la reunión próxima.
5. Las encuestas horizontales deberían ser practicadas cada 5 o 10 años, para verificar el valor del trabajo efectuado.
6. El tipo de fichas establecido por el Grupo de Trabajo debe ser utilizado por todos los Centros.

A lo largo de este trabajo se podran apreciar los progresos realizados a partir de este pequeño núcleo inicial. ¿De qué manera conducir progresivamente ocho grupos distintos a ponerse de acuerdo sobre los principios en cuestión? ¿Cómo imaginar que las diferentes disciplinas representadas puedan llegar a comprenderse y a preparar formas comunes de prospección? La barrera del idioma era ya, por si sola, un obstáculo. ¿Cómo fue superada? ¿De qué modo continúa siéndolo hoy día?

En primer lugar, gracias al estímulo constante que provoca en los países representados la necesidad de disponer de informaciones respecto del crecimiento; en seguida, gracias al espíritu de competencia. Es un excelente estímulo, en el seno de un gran equipo, desear que el propio sea el mejor. Pero lo que fue más importante es que había nacido una familia, una familia de la cual Nathalie Masse había llegado a ser la madre, en el mejor sentido del término, y cuyos miembros eran los diferentes Equipos de trabajo. Nos fuimos conociendo mejor poco a poco, alegrandonos de antemano de la perspectiva de las reuniones familiares. ¡Sin luchas intestinas, una familia sería bien insípida! La nuestra también ha tenido las suyas, como sucede hasta en las mejores familias. Pero rápidamente sosegadas, ellas contribuyeron a reforzar las amistades y a mejorar la calidad del trabajo.

Resumen de las etapas sucesivas y de las orientaciones posteriores

En varias ocasiones fueron designados como coordinadores en cada campo importante de investigación algunos Directores de equipo. C. Hindley, en psicología; P. Karlberg, en análisis; J. M. Tanner, en crecimiento somático. El autor tuvo a su cargo la coordinación general, en colaboración con el C.I.I. Hubo primero reuniones anuales, en seguida cada dos años, que tuvieron lugar en los Centros de Investigación europeos. El examen de las actas de dichas reuniones revela la serie de hechos sobresalientes que han ido jalonando el progreso de los equipos y el avance de sus respectivos trabajos.

Pueden notarse las etapas siguientes:

1954: París — en que se reunió el primer grupo de trabajo. En seguida,

1955: Estocolmo — Aún cuando los investigadores eran aún poco numerosos, en esta ocasión estuvieron presentes todos los equipos coordinados. Fue entonces que P. Karlberg suscitó por vez primera la cuestión del **análisis estadístico** de los resultados y lanzó la idea de la oportunidad de establecer fichas de observación susceptibles de ser computabilizadas. En el curso del mes siguiente se llevó a efecto un considerable trabajo de codificación y normalización de fichas.

1956: Londres — M. Graffar dio cuentas de los resultados preliminares de una escala numérica de **clasificación social,** que tomaba en consideración una gran cantidad de factores. El uso de esta escala se ha extendido actualmente al mundo entero.

1958: Bruselas — Esta reunión se ha señalado por numerosos hechos:

1. La publicación de los primeros **resultados comparados** del trabajo de varios equipos;
2. La profundizada discusión respecto de los métodos de evaluación de la **maduración ósea.** La técnica del método de Tanner y Whitehouse fué publicada por el C.I.I. en 1962.
3. El informe de J. Sénécal y M. Geber sobre **el desarrollo precoz** de los niños de Senegal y de Uganda en sus primeros meses de vida.
4. Finalmente, por vez primera, investigadores provenientes de Centros diferentes, pero interesados en los mismos problemas que nosotros, formaron parte de la reunión y dieron cuenta de sus respectivas experiencias. De esta manera se formó una red de «amigos» estrechamente ligada a nuestro grupo.

1960: Zurich — Realizada inmediatamente después de un Seminario Internacional sobre «El Crecimiento del Niño Normal en el curso de sus tres primeros años», esta reunión se señaló por los informes presentados por R. F. A. Dean acerca del papel de la **nutrición.** Desgraciadamente, el estudio de Kampala fue interrumpido debido al desaparecimiento de nuestro colega Dean. Posteriormente, M. Geber ha dado a conocer, en numerosas ocasiones, los aspectos psicológicos de dicho estudio.

1962: Londres — Los Equipos abordaron el problema del **método estadístico** aplicado a los estudios longitudinales.

1964: París — Se establecen los protocolos de observación de la **pubertad** en los muchachos y muchachas.

1966: Estocolmo — Los Equipos de Estocolmo, Londres y Bruselas dieron a conocer datos longitudinales acerca del **desarrollo psicológico.**

1968: Bruselas — El debate se centró, entre otros temas, alrededor de la influencia de los **factores sociales.**

1970: Davos — Por primera vez, los equipos de Londres, Zurich y París dieron cuenta de un análisis respecto del **crecimiento patológico.**

1972: Londres — El debate se realizó en torno a **la pubertad, la maduración ósea** y **la metodología estadística.**

1974: París — La progresión de los estudios y el avance en edad de los niños de las muestras fueron tomados en cuenta en varias comunicaciones. Entre éstas se destacaron las de C. Hindley acerca del desarrollo de aptitudes entre los 6 meses y los 17 años, en función de determinados parámetros y las de M. P. Roy, E. A. Sand, E. A. Werder y A. F. Roche sobre el crecimiento durante la adolescencia y sobre la previsión de la talla adulta, respectivamente.

Al final de esta reunión, C. Hindley presentó los Planes para el futuro y Nathalie Masse su informe sobre «Veintiuno Años de Investigaciones Coordinadas», del cual hemos hablado ya.

1976: Rennes — Los Equipos de Psicología y de Estudios Somáticos, en colaboración con «amigos», presentaron experiencias ceñidas particularmente a los aspectos longitudinales de los estudios. Un tiempo adecuado fue concedido al examen de algunos aspectos matemáticos más bien complejos relativos a los análisis de datos.

1978: Göteborg — El tema principal de este encuentro estuvo constituído por el porvenir. Es decir, y después de un resumen del trabajo efectuado por los Equipos hasta el momento, el examen de las tareas por hacer con los datos ya recogidos y, finalmente, las actividades futuras, a desarrollar mediante la colaboración de los diferentes equipos.

En cada una de las reuniones señaladas fueron tratados, naturalmente, todos los problemas atingentes al programa de investigaciones; sin embargo, el autor ha juzgado más interesante mostrar como fueron presentandose de modo espontáneo todos los problemas y líneas de orientación que más tarde habrían de asumir una gran importancia.

Balance y estado actual de los trabajos

Los informes detallados de la situación actual de los bancos de datos de cada uno de los Equipos serán presentados más adelante. A continuación proporcionaremos una visión general.

Todos los Equipos constituídos entre 1953 y 1955 continúan formando parte del grupo. Como ha sido dicho, el Equipo de Kampala debió ser suspendido debido al lamentable fallecimiento de R. F. A. Dean. Sin embargo, M. Geber ha realizado numerosas estadías en ese lugar con el fin de continuar viendo algunos niños desde el punto de vista psicológico. El Equipo de Dakar ha cesado de recoger datos al cabo de 6 años. Pero la mayor parte de los niños han sido vueltos a contactar a los doce años; actualmente son seguidos regularmente de nuevo.

El tamaño de las muestras varía considerablemente de uno a otro centro. Pero todos los equipos han podido seguir las directivas sobre crecimiento somático y efectuar las observaciones respecto del medio socioeconómico. El aspecto psicológico de las encuestas cesó a la edad de 6 años en Dakar y en París; en Zurich ha sido sólo parcialmente abordado. Bastantes Equipos han ido mucho más allá de lo previsto en el protócolo. En especial, el Equipo de Estocolmo en materia de psicología, el Equipo de Londres en osificación y los Equipos de Zurich y de París en el tema de las influencias patológicas en el crecimiento y el desarrollo.

Algunas reflexiones

Ha surgido la pregunta acerca de aquello que las encuestas coordinadas han estado en condiciones de hacer y de lo que no han podido realizar. Evidentemente ellas han estado limitadas en recursos económicos y de personal. En consecuencia, las muestras han debido ser de reducidas dimensiones y los datos precisos obtenidos no alcanzan sino un volumen restrigido, particularmente los que se refieren a exploraciones psicológicas. Por otra parte, el análisis de la importante cantidad de datos acumulados ha sido limitado. En cuanto a las muestras mismas, dado que todo estudio longitudinal exige una cooperación continuada largo tiempo y conlleva una pérdida selectiva de la muestra, es preciso decir que no se puede pretender que ellas estén absolutamente escogidas al azar, estratificadas o verdaderamente apropiadas para suministrar dator normativos. De todos modos, es preciso decirlo, los resultados han sido y continúan siendo utilizados en ciertos países (en Bélgica, por ejemplo); quizá a causa de no haber otros datos disponibles.

Podría objetársenos el no haber formulado claramente, a comienzo de los años 50, un cierto número de hipótesis a verificar. Sin embargo, pensamos haber procedido bien absteniéndonos. Para citar un solo ejemplo: suponiendo que hubiésemos formulado nuestros programas con el mayor cuidado y emitido hipótesis voluntariamente restringidas, no hubiéramos podido disponer, en esos años, sino de métodos primitivos de análisis. A medida que fuimos avanzando, los progresos de la técnica y de la biometría nos fueron permitiendo tratar una serie de datos impensables al comienzo. De hecho, una de las consecuencias recientes de estos progresos ha sido el interés demostrado por los especialistas de la estadística matemática frente a nuestros problemas (lo que es ya una hazaña) y cuyo contacto nos ha permitido aprender mucho.

Además, con el correr del tiempo, el análisis de datos no ha cesado de originar nuevas hipótesis, suscitando, en consecuencia, nuevos estudios longitudinales o semilongitudinales destinados a verificar dichas hipótesis.

En este punto, es necesario reconocer que, en nuestros estudios, los datos somáticos no han estado suficientemente ligados a los datos psicológicos, perpetuandose así una laguna al parecer común a todos los estudios pluridisciplinarios sobre el crecimiento y el desarrollo.

Volviendo a las limitaciones de un sistema que consiste en utilizar las informaciones provenientes de estos estudios, no sería razonable rechazarlos por un prurito de perfeccionismo. La principal ventaja de los estudios longitudinales descansa en el hecho de que las modificaciones observadas en individuos o grupos no pueden provenir sino de cambios reales y en ningún caso de errores de medida. En el hecho, son muy raros los estudios científicos realizados en niños — sean ellos somáticos, psicológicos o biomédicos — cuyas muestras puedan ser consideradas como imparciales o bien obtenidas sobre una amplia población.

La naturaleza misma de las prospecciones y de los estudios nos evita permanecer a la defensiva en materia, por ejemplo, de muestreo, ya que las modificaciones del desarrollo, pasadas o futuras, volverán a encontrarse más que probablemente en el conjunto de la población. A partir del hecho de que los Equipos trabajan con muestras diferentes, es posible efectuar contra-pruebas, lo cual, como se ha dicho, incita a nuevas comprobaciones más adelante y en otros lugares. En todo caso, es preciso insistir en un factor crucial, simple, pero raramente tomado en serio: crecimiento y desarrollo son procesos que se manifiestan en el indivíduo y solamente en el indivíduo. Hindley y Owen (1979) lo indican de modo suscinto al afirmar que los datos llamados científicos sobre el desarrollo, establecidos a partir de medianas en un grupo de edades diferentes, no dan cuenta de las modificaciones del desarrollo de ningún indivíduo en particular. Si acaso interesa verdaderamente saber de qué manera cambian los niños con la edad (cambios que son puestos en evidencia por los datos del grupo) también conviene estudiar los cambios durante el crecimiento y desarrollo de cada niño, así como las diferencias individuales en las tendencias del desarrollo. Los Equipos están en situación de realizar este trabajo.

Conviene mencionar la carencia mundial de datos longitudinales a largo plazo. Solo se encontran en algunos estudios, particularmente en los Estados Unidos. El trabajo efectuado por los Equipos ha aportado aquí un complemento de importancia.

Sería necesario referirse, a continuación, a ciertos resultados y aportes indirectos que surgen del trabajo de los Equipos.

1. Aplicaciones a la Pediatría Social y a la Salud Pública

Aun cuando han sido criticados por su corta extensión los estudios han tenido influencia en la pediatría preventiva y social y han impulsado a diversos países al establecimiento de referencias, cuadros y gráficos actualmente utilizados por los servicios de Pediatría, de Salud Infantil y de Higiene Escolar. Algunos miembros de los Equipos han colaborado con la O.M.S. en el establecimiento de tablas internacionales de referencias contribuyendo así a la tendencia actual de utilizar las características del crecimiento infantil como indicadores del estado sanitario y nutricional de una población determinada.

2. Aplicación a la Medicina Clínica

La aparición de un método riguroso de análisis del crecimiento y la maduración ha permitido perfeccionar la sintomatología pediátrica y describir las anomalías propias de las diferentes enfermedades de las glándulas endocrinas o del metabolismo.

3. Aplicación a la Enseñanza

La enseñanza impartida a estudiantes y futuros especialistas utiliza con largueza los datos recogidos por los Equipos. Esto se facilita por el hecho de que casi siempre los Centros están agregados a los Departamentos de Pediatría de las Universidades. Estos mismos da-

tos son también abundantemente utilizados por los profesores del C.I.I.

4. Intercambio de experiencias con el grupo de «amigos»

Con el correr de los años, la colaboración con otros investigadores o «amigos» ha sido un estímulo y una fuente apreciable de informaciones recíprocas.

¿Qué pensar del porvenir?

La mayor parte de los Equipos posee una cantidad de datos válidos, recogidos por investigadores experimentados, sectores de los cuales no han sido jamás analizados, particularmente aquellos que conciernen la parte «psicológica» de los estudios, como por ejemplo la creatividad, los intereses, el comportamiento, los valores, los resultados escolares, tanto en su devenir temporal como en sus interacciones. No ha sido analizada aún la relación de estos factores nombrados — o de otros factores o estados psicológicos — con el crecimiento somático. Una tal exploración no solamente permitiría eliminar una crítica justificada de las encuestas longitudinales pluridisciplinarias, sino también concitar abundante trabajo conexo en el futuro.

Es necesario no echar al olvido los datos específicos concernientes a cada indivíduo, válidos y subsistentes aún cuando éstos hayan alcanzado la madurez. El seguimiento de los sujetos hasta ciertos estadios de su vida adulta suministraría otros datos específicos y daria respuesta a algunos problemas de la biología humana que sólo por esta vía podrían resolverse. También aquí el campo de las encuestas comparativas inter-centros aparece como muy vasto.

De todas estas consideraciones se desprende que sería altamente provechoso que los Equipos no perdieran jamás contacto con sus cohortes y continuaran reuniéndose para la prosecución de sus trabajos coordinados. La realización de estos trabajos depende — es necesario decirlo — de los apoyos financieros y de otra índole en momentos difíciles. En este sentido, habrá necesidad tanto de esfuerzos personales como colectivos. El mejor modo de lograrlo será, quizá, otorgar prioridad a la investigación científica: de ella podemos esperar el mejoramiento de la salud y el bienestar de los hombres.

Ventajas más intangibles que proporcionan los Estudios

Los miembros de los Equipos, cualquiera sea su responsabilidad, están todos de acuerdo en manifestar de qué manera les ha sido provechoso el conocimiento de las opiniones y las experiencias de otros investigadores en campos vecinos al suyo: no sólo les ha permitido mejorar la calidad de su trabajo, sino también perfeccionar su propia formación. Los miembros de los Equipos se han instruido con provecho en disciplinas diferentes de la propia. Existe un caso que merece ser relatado: la experiencia adquirida por el Equipo de Bruselas en la encuesta sobre los parametros de las clases sociales y que permitió a muchos de nosotros aprender métodos de evaluación más eficaces que los que hubiéramos adquirido de otra manera. Este tipo de colaboración ha permitido abrir los ojos sobre las diferencias — modos de vida y educación de los niños — que se dan en otros países así como las relaciones existentes entre dichos factores y el crecimiento to y desarrollo de los individuos.

Con toda modestia, podríamos decir que la colaboración y la coordinación permanentes entre los Equipos han alentado y estimulado el estudio del crecimiento y desarrollo en muchos países, especialmente en aquellos en vías de desarrollo, contribuyendo de este modo al mejoramiento de la salud infantil.

Finalmente, es necesario señalar un resultado considerable: la creación, con el transcurso de los años, de un beneficio definitivo como son las amistades adquiridas tanto en el plano científico como en personal. Para el autor, estas amistades son particularmente valiosas.

Some international comparisons of physical growth in the two first years of life *

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Certain international studies of the growth and development of the child have agreed to carry out similar investigations to each other in similar manner and thus afford the opportunity to compare data. All the studies involved are multi-disciplinary and longitudinal, and the children are seen from birth. Because not all the studies started at the same time the children in one country are not necessarily the same age as those in another at any one time, but all the children involved were born after 1952.

For details of the history, organization, and investigations in progress, reference may be made to Moore et al. (1954) and Falkner (1954, 1955, 1958 i et ii). Briefly, the *same* children are followed regularly from birth and are seen between rigid time limits. The samples are not selected and in the case of the European children are so called «healthy». African children taking part in the study will need more comment later.

This paper gives the first comparative data from these studies and concerns certain physical measurements in the first two years of life. The children involved are from the London, Paris, Zurich, and Dakar studies.

MEASUREMENTS

All measurements were taken by trained personnel and it is the policy of the studies to limit the number of measurers to the minimum. In most cases this is two for each study. Lincoln (1930) had shown the very great improvement in accuracy after the training of measurers.

INCREMENTS

Known gains in measurements are a valuable indication of speed of growth, and Krogman (1956) has deplored the neglect of this aspect of growth analysis. Unfortunately incremental data calculated from cross-selectional material continue to find their way into the literature. In these longitudinal studies naturally only children seen at the beginning and the end of an incremental period may be, and are, included for calculation of mean increments, for not every child is able to be measured at every appointed time. "Adjusted mean increments" will be used and this term needs explanation: it was convenient to use exactly 13 weeks (approximately 3 months) as the standard comparative period. Not every period is in fact, 13 weeks and when this is so (e.g., 4 to 13 weeks) the figures are adjusted to bring them to the comparable 13 week interval. This does presume that the rate of growth at the times involved is a linear curve and this may not in fact be so. But as the ages involved are so close together this procedure is felt to be permissible.

WEIGHT

All children were weighed nude on checked basket scales, and, when able to stand, on checked platform beam balances.

There is great similarity in mean weights in the European children, but both boys and girls of the Dakar children may be said to have a tendency to be heavier up to approximately six months of age; and then tend to be lighter.

Regarding increments, again the European children are similar, but the Dakar children are gaining weight faster at 3 months, and then again consistently less. Some discussion on this will follow after the recumbent length data have been presented.

RECUMBENT LENGTH

All measurements were taken with the children lying nude on a horizontal measuring table. (Such tables have been developed by Todd at Western Reserve and Thompson at Yale Universities; and by Knott (1941), Hindley (1953), and Falkner (1958 i). The technique is well summarized by Krogman (1950). The measurement represents the distance between the crown of the head and the base of the heels.

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* Published in "Courrier", C.I.E., 1958, 8, 1-11.

TABLE 1

BOYS				Age			GIRLS			
London	Paris	Zurich	Dakar				London	Paris	Zurich	Dakar
96	—	205	—		Birth	No.	93	—	199	—
3.46	—	3.36	—	Mean wt.	»	Mean wt.	3.23	—	3.27	—
2.67	—	2.47	—	5th P	»	5th P	2.31	—	2.46	—
4.30	—	4.20	—	95th P	»	95th P	3.99	—	4.09	—
—	—	—	168	No.	10 days	No.	—	—	—	161
—	—	—	3.55	Mean wt.	»	Mean wt.	—	—	—	3.40
—	—	—	2.77	5th P	»	5th P	—	—	—	2.73
—	—	—	4.20	95th P	»	95th P	—	—	—	4.08
82	161	81	—	No.	4 wks	No.	77	166	97	—
4.05	3.95	3.94	—	Mean wt.	»	Mean wt.	3.73	3.75	3.70	—
3.17	3.29	2.94	—	5th P	»	5th P	2.94	3.16	2.89	—
4.89	4.80	4.80	—	95th P	»	95th P	4.39	4.56	4.45	—
96	145	76	144	No.	13 wks	No.	84	136	93	143
5.91	5.84	5.81	6.42	Mean wt.	»	Mean wt.	5.39	5.38	5.36	5.80
4.89	4.89	4.77	5.23	5th P	»	5th P	4.30	4.38	4.28	4.51
7.11	6.07	6.91	7.65	95th P	»	95th P	6.20	6.27	6.46	7.02
94	153	81	145	No.	26 wks	No.	81	141	96	140
7.91	7.67	7.68	8.04	Mean wt.	»	Mean wt.	7.43	7.11	7.12	7.26
6.61	6.34	6.40	7.00	5th P	»	5th P	5.93	5.73	5.74	5.75
9.01	8.91	9.55	9.94	95th P	»	95th P	8.92	8.38	8.45	8.90
84	130	81	143	No.	39 wks	No.	78	115	93	139
9.25	8.95	9.13	8.69	Mean wt.	»	Mean wt.	8.69	8.44	8.39	8.11
7.38	7.27	7.60	7.38	5th P	»	5th P	6.70	6.56	6.66	6.44
10.92	10.88	11.09	10.24	95th P	»	95th P	10.69	10.02	9.68	9.49
81	125	78	147	No.	1 yr	No.	78	114	84	129
10.15	9.83	10.18	9.21	Mean wt.	»	Mean wt.	9.64	9.22	9.47	8.58
7.70	8.05	8.56	7.78	5th P	»	5th P	7.88	7.52	7.64	6.94
11.91	11.43	12.32	10.76	95th P	»	95th P	11.73	11.23	11.16	10.64
74	96	69	—	No.	18 mos	No.	67	78	84	—
11.50	11.24	11.62	—	Mean wt.	»	Mean wt.	10.85	10.61	10.89	—
9.10	9.32	9.59	—	5th P	»	5th P	8.97	8.84	9.16	—
12.91	13.19	13.81	—	95th P	»	95th P	12.68	12.56	12.58	—
57	67	33	—	No.	2 yrs	No.	57	58	45	—
12.48	12.28	12.89	—	Mean wt.	»	Mean wt.	11.81	11.71	12.01	—
9.97	10.29	10.46	—	5th P	»	5th P	9.74	9.31	9.95	—
14.45	14.40	15.77	—	95th P	»	95th P	14.18	13.79	13.88	—

Mean weights at stated ages of London, Paris, Zurich, and Dakar children in kilograms to the nearest 10.0 grams. 5th and 95th percentiles given.

TABLE 2

BOYS				Age			GIRLS			
London	Paris	Zurich	Dakar				London	Paris	Zurich	Dakar
73	—	79	—	No.	at 4 wks	No.	72	—	95	—
2.00	—	1.57	—	Mean Adj.		Mean Adj.	1.64	—	1.31	—
			Inc.		Inc.					
77	105	77	144	No.	at 13 wks	No.	65	115	93	143
2.74	2.60	2.72	3.23	Mean Adj.		Mean Adj.	2.42	2.36	2.40	2.71
			Inc.		Inc.					
87	114	76	127	No.	at 26 wks	No.	73	104	96	126
2.01	1.80	1.89	1.54	Mean Adj.		Mean Adj.	2.05	1.73	1.76	1.44
			Inc.		Inc.					
80	107	79	127	No.	at 39 wks	No.	69	88	94	123
1.45	1.32	1.42	0.77	Mean Adj.		Mean Adj.	1.30	1.28	1.29	0.65
			Inc.		Inc.					
72	99	77	133	No.	at 52 wks	No.	69	82	89	124
0.86	0.90	1.03	0.52	Mean Adj.		Mean Adj.	0.93	0.82	1.05	0.42
			Inc.		Inc.					
60	83	66	—	No.	at 18 mos	No.	59	62	82	—
0.66	0.65	0.69	—	Mean Adj.		Mean Adj.	0.62	0.67	0.70	—
			Inc.		Inc.					
51	56	31	—	No.	at 2 yrs	No.	48	46	41	—
0.53	0.49	0.54	—	Mean Adj.		Mean Adj.	0.53	0.52	0.59	—
			Inc.		Inc.					

Mean "adjusted" increments of weight in 13 week-periods at stated ages of London, Paris, Zurich and Dakar children, in kilograms to the nearest 10.0 grams.

The European children are very similar in recumbent length achieved and the Dakar children are not noticeably different, except they tend to be smaller by one year of age. Here is a good example of how incremental data brings out an important fact: If increments and their curves are examined, the Dakar children are seen to be growing at a very much faster rate in the early days of life. Between six and nine months, however, they drop to a lower rate than the European children. Figure I graphically depicts some data from Table 4. Increments of boys and girls in height gain in early childhood are very similar and here they are combined.

DISCUSSION

Table 5 shows that comparing mean increments of one of the European samples (London) with those of the Dakar children there is a highly significant difference for boys and girls, and the sexes combined, at 13 weeks of age ($P = -001$). There was no significant difference between the sexes for each sample.

The Dakar children are practically all breast fed and breast milk is available in virtually unlimited quantities. In the tropics this may lead to increased osteogenesis (see later in text) and chondroplasia. (There is some impression in temperate climates that

TABLE 3

BOYS				Age			GIRLS			
London	Paris	Zurich	Dakar				London	Paris	Zurich	Dakar
—	—	205	—	No.	No.—	—	196	—		
—	—	50.5	—	Mean hgt.	Birth	Mean hgt.	—	—	49.8	—
—	—	2.2	S.D.		S.D.	—	—	2.2	—	
—	—	—	163	No.		No.	—	—	—	158
—	—	—	52.0	Mean hgt.	10 days	Mean hgt.	—	—	—	51.0
—	—	—	1.9	S.D.		S.D.	—	—	—	2.1
82	162	85	—	No.		No.	77	169	195	—
53.9	53.2	54.0	—	Mean hgt.	4 wks	Mean hgt.	52.5	52.5	53.1	—
2.3	2.1	2.3	—	S.D.		S.D.	1.8	2.0	1.4	—
96	143	76	143	No.		No.	85	136	93	142
60.2	60.0	60.8	62.0	Mean hgt	13 wks	Mean hgt.	58.2	58.7	59.3	60.0
2.4	2.2	1.9	2.2	S.D.		S.D.	1.6	2.2	2.1	2.1
94	150	80	143	No.		No.	81	140	95	137
66.7	66.6	67.8	67.5	Mean hgt.	26 wks	Mean hgt.	64.8	64.8	65.9	65.0
2.4	2.3	2.1	2.1	S.D.		S.D.	2.6	2.3	2.1	2.4
84	129	80	143	No.		No.	78	113	91	137
71.3	70.8	72.6	71.0	Mean hgt.	39 wks	Mean hgt.	69.5	69.2	70.6	69.0
2.6	2.2	2.3	2.1	S.D.		S.D.	2.6	2.4	2.3	2.4
80	122	79	146	No.		No.	78	114	93	128
75.0	74.3	76.2	74.0	Mean hgt.	1 yr	Mean hgt.	73.3	72.6	74.2	72.5
2.7	2.2	2.3	2.2	S.D.		S.D.	2.6	2.6	2.6	2.5
77	96	70	—	No.		No.	66	78	83	—
81.2	80.5	82.3	—	Mean hgt.	18 mos	Mean hgt.	79.7	79.1	80.5	—
3.2	2.9	2.9	—	S.D.		S.D.	2.4	2.8	2.6	—
55	68	34	—	No.		No.	54	58	45	—
86.5	85.9	87.9	—	Mean hgt.	2 yrs	Mean hgt.	84.5	84.4	86.0	—
3.7	2.9	3.2	—	S.D.		S.D.	3.1	3.4	3.1	—

Mean recumbent-lengths in cms, to the nearest mm, at stated ages of London, Paris, Zurich, and Dakar children. ± 1 S.D. of the mean given.

the same nutrition might lead to increased fat formation.) By nine months of age, malnutrition (comparatively) in this sample of children may be starting to make itself felt and offers an explanation of their falling below the velocity of the European children.

This is almost certainly not the only explanation and racial and genetic factors are involved. Some facts seem to show that the African is born more mature biologically (e.g., Dean, 1956; Allbrook, 1956; Geber et Dean, 1957; Falkner, 1958 ii), and the above data would appear to confirm this in the measurements discussed.

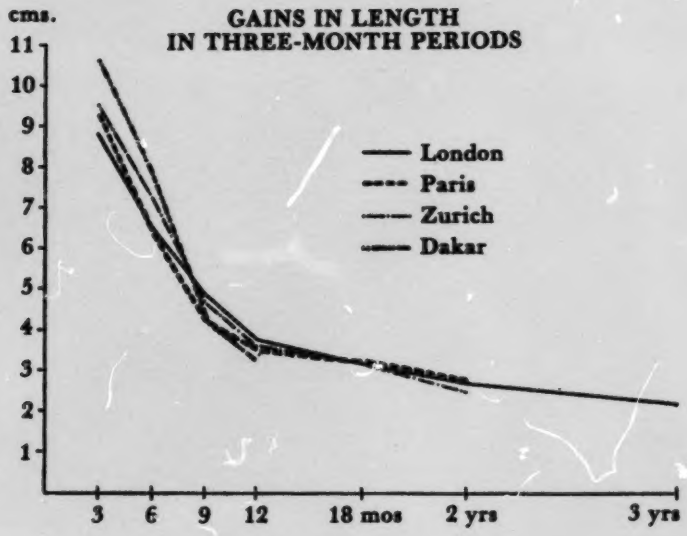

TABLE 4

BOYS				Age			GIRLS			
London	Paris	Zurich	Dakar				London	Paris	Zurich	Dakar
— —	— —	78 9.5	— —	No. Mean AIH	at 4 wks	No. Mean AIH	— —	— —	90 9.6	— —
68 9.1	105 9.6	76 9.0	138 10.8	No. Mean AIH	at 13 wks	No. Mean AIH	66 8.6	117 8.9	92 9.3	140 10.1
87 6.4	113 6.5	76 7.0	126 5.5	No. Mean AIH	at 26 wks	No. Mean AIH	74 6.7	103 6.2	94 6.6	123 5.2
80 4.8	105 4.3	80 4.7	124 3.8	No. Mean AIH	at 39 wks	No. Mean AIH	69 4.7	87 4.0	92 4.7	117 4.0
71 3.7	95 3.4	77 3.5	133 2.9	No. Mean AIH	at 1 yr	No. Mean AIH	69 3.8	82 3.5	88 3.6	122 2.9
63 3.1	83 3.0	69 3.1	— —	No. Mean AIH	at 18 mos	No. Mean AIH	58 3.2	62 3.2	76 3.1	— —
51 2.6	57 2.5	33 2.4	— —	No. Mean AIH	at 2 yrs	No. Mean AIH	45 2.6	46 2.6	41 2.5	— —

Mean "adjusted" increments of recumbent length in 13 week-periods at stated ages in cms, to the nearest mm, of London, Paris, Zurich, and Dakar children ("AIH": Adjusted increments of height).

Table 5

				Dakar		London	
	t	df	p	mean	s.d.	mean	s.d.
Boys	5.72	213	.001	10.83	2.19	9.07	2.07
Girls	5.38	206	.001	10.05	1.86	8.57	1.84
Total	7.64	421	.001	10.44	2.08	8.84	1.98

Recumbent-length velocity of two samples compared at 13 weeks of age

TABLE 6

BOYS			Age			GIRLS		
London	Paris	Dakar				London	Paris	Dakar
— —	— —	94 0.4	No. Mean	10 days	No. Mean	— —	— —	16 0.8
70 0.3 (0.06-2.1)	124 0.1	— —	No. Mean	4 weeks	No. Mean	68 0.5 (0.07-2.2)	128 0.4	— —
83 1.2 (0.2-2.4)	137 1.2	77 1.7	No. Mean	13 weeks	No. Mean	71 1.4 (0.2-3.0)	137 1.8	33 2.0
81 2.5 (0.6-4.8)	140 2.8	110 3.0	No. Mean	26 weeks	No. Mean	73 2.7 (1.1-4.5)	131 3.5	39 2.8
66 3.3 (1.3-6.2)	127 3.7	68 3.7	No. Mean	39 weeks	No. Mean	61 3.9 (0.4-7.6)	114 4.6	33 3.4
59 4.3 (1.7-8.2)	131 4.6	52 4.3	No. Mean	52 weeks	No. Mean	56 6.2 (1.8-11.2)	112 5.8	22 4.6
64 6.3 (3.3-9.5)	85 6.2	16 5.1	No. Mean	18 mos	No. Mean	55 9.6 (5.1-13.1)	73 8.9	27 5.3
46 8.8 (4.2-13.3)	52 8.3	7 5.4	No. Mean	2 yrs	No. Mean	39 12.1 (8.6-15.1)	48 11.3	5 6.2

Mean Oxford Points of London, Paris, and Dakar children to the nearest 0.1 points. Hand and wrist at stated ages. The figures in parentheses in the London children indicate the 5th and 95th percentiles for purposes of a demonstration of distribution.

TABLE 7

BOYS			Age			GIRLS		
London	Paris	Dakar*				London	Paris	Dakar*
58 1.2	88 1.1	77 1.4	No. Mean	at 13 wks	No. Mean	48 1.5	87 1.8	53 1.4
70 1.4	101 1.7	110 2.3	No. Mean	at 26 wks	No. Mean	56 1.3	95 1.7	39 1.8
50 1.1	92 0.9	68 0.7	No. Mean	at 39 wks	No. Mean	49 1.2	79 1.3	33 0.6
40 0.9	86 0.9	52 0.6	No. Mean	at 52 wks	No. Mean	40 2.8	78 1.3	22 1.2
43 1.0	87 0.9	16 0.5	No. Mean	at 18 mos	No. Mean	37 1.8	60 1.5	27 0.3
32 1.4	48 1.0	— —	No. Mean	at 2 yrs	No. Mean	26 1.4	47 1.2	— —

Mean "adjusted" increments of Oxford points (to the nearest 0.1 points) in 13 week-periods at stated ages.
*Note: The Dakar increments are by substraction of means and are thus only an approximation.

SKELETAL MATURITY

The teams assessed skeletal maturity using the method of Acheson (1954)—The Oxford Method—in which, using the hand and wrist, points are given to individual centres on appearance and on shape changes. These are known as Oxford Points. The method is reliable in the hands of different observers and gives an adequate measure of skeletal maturity. (Acheson, 1957; Falkner, 1958 ii.)

DISCUSSION

The greater maturity of the female over the male skeletally was first noted by Pryor (1925) and this has often been described since and is present from birth (e.g., Todd, 1937; Greulich & Pyle, 1950; Acheson, 1954; Tanner, 1955; Falkner, 1957 ii, etc.). However, there appears to be no advance of one sex over the other in the Dakar children in the age period under discussion. Mackay (1952) noted that there was little difference at six months of age in a sample of East African children, yet as age increases year by year, the female soon advances over the male. It seems possible therefore that the African child does not develop this sex difference until at least after one year of age.

The second most interesting feature is that although the London and Paris children (Zurich data was unfortunately unavailable for this section) are very similar in their state of skeletal maturity, the Dakar children tend to be more advanced in the early weeks following birth, but that they lose this advance and tend to fall behind by 18 months of age. Falkner (1958 ii) has shown that, in the main, in health, growth in height and skeletal maturity status are closely related and these data on skeletal maturity seem to confirm the findings discussed under recumbent-length data.

DECIDUOUS TOOTH ERUPTION

For the purposes of this paper the status of eruption was gauged by counting the total number of deciduous teeth erupted—the definition of eruption being that stage when part of the crown of the tooth has pierced the gum (Robinow et al., 1942; Doering & Allen, 1942; Falkner, 1957 ii, 1958 i).

TABLE 8

BOYS				Age			GIRLS			
London	Paris	Zurich	Dakar				London	Paris	Zurich	Dakar
96	—	—	—	No.		No.	96	—	—	—
0	—	—	—	Mean No.	4 wks	Mean No.	0	—	—	—
—	—	—	—	S.D.		S.D.	—	—	—	—
93	—	—	—	No.		No.	91	—	—	—
0.01	—	—	—	Mean No.	13 wks	Mean No.	0	—	—	—
0.1	—	—	—	S.D.		S.D.	—	—	—	—
90	153	33	122	No.		No.	84	141	48	124
0.4	0.4	0.5	0.4	Mean No.	26 wks	Mean No.	0.4	0.3	0.3	0.5
1.1	1.0	—	—	S.D.		S.D.	0.8	0.8	—	—
85	135	33	133	No.		No.	76	118	48	130
2.5	3.0	2.9	2.8	Mean No.	39 wks	Mean No.	3.1	2.8	2.1	2.8
2.2	2.3	—	2.1	S.D.		S.D.	2.5	2.4	—	2.4
82	136	33	140	No.		No.	77	121	48	123
6.2	6.0	5.9	5.2	Mean No.	1 yr	Mean No.	6.1	5.6	4.9	5.8
2.8	2.2	—	2.1	S.D.		S.D.	2.3	2.5	—	2.7
79	96	33	116	No.		No.	68	76	48	114
12.6	12.5	12.5	12.1	Mean No.	18 mos	Mean No.	13.0	12.1	11.9	12.6
3.3	3.0	—	—	S.D.		S.D.	2.7	2.9	—	—
59	66	33	86	No.		No.	57	57	48	78
16.3	16.3	16.7	17.6	Mean No.	2 yrs	Mean No.	16.3	16.5	15.8	17.4
1.8	2.5	—	—	S.D.		S.D.	1.9	2.8	—	—

Means of total teeth erupted to nearest 0.1 tooth, at stated ages for London, Paris, Zurich, and Dakar children.

In deciduous dentition there has been some suggestion (Robinow et al., 1942; Doering & Allen, 1942; Meredith, 1946; Mackay & Martin, 1952) that the male is advanced over the female, but this was not able to be demonstrated by Falkner (1958 ii) after closely spaced examinations. The data here show no tendency for any such advance of one sex over the other.

The data show that there is a good similarity between the European and Dakar children and perhaps at first this may be thought surprising. It is suggested that with the adequate quantities of breast milk available, deciduous dentition is presumably not affected though it might have been suspected of being so by inadequate maternal ante-natal nutrition. Again the genetic element in racial characteristics is large and dentition is certainly largely influenced by this factor (Tisserand-Perrier, 1953).

CONCLUSION NOTE

It will be remarked that the studies in question are longitudinal and the children involved are being followed regularly. Therefore many of the questions raised in these discussions will be assessed from time to time at later dates.

TABLE 9

BOYS				Age			GIRLS			
London	Paris	Zurich	Dakar				London	Paris	Zurich	Dakar
92	—	—	—	No.		No.	91	91	—	—
0.01	—	—	—	Mean Inc.	4w-13w	Mean Inc.	0	0	—	—
—	—	—	—	S.D.		S.D.	—	—	—	—
86	107	33	—	No.		No.	83	91	48	—
0.3	0.4	0.5	—	Mean Inc.	13w-26w	Mean Inc.	0.3	0.3	0.3	—
0.8	—	—	—	S.D.		S.D.	0.7	—	—	—
79	107	33	98	No.		No.	70	91	48	95
2.0	2.6	2.2	2.0	Mean Inc.	26w-39w	Mean Inc.	2.7	2.3	1.9	2.2
1.7	—	—	—	S.D.		S.D.	2.0	—	—	—
74	100	33	114	No.		No.	68	85	48	107
3.7	3.1	3.2	2.9	Mean Inc.	39w-52w	Mean Inc.	2.9	2.9	2.5	2.7
2.1	—	—	—	S.D.		S.D.	1.7	—	—	—
65	100	33	116	No.		No.	58	71	48	114
3.0	3.2	3.3	3.4	Mean Inc.	1y-18m	Mean Inc.	3.4	3.2	3.3	3.4
1.2	—	—	—	S.D.		S.D.	1.2	—	—	—
56	65	33	86	No.		No.	49	60	48	78
1.9	1.9	2.0	2.8	Mean Inc.	18m-2y	Mean Inc.	1.5	2.2	2.0	2.4
1.3	—	—	—	S.D.		S.D.	1.0	—	—	—

Mean "adjusted" increments in 13 week-periods of total teeth erupting to nearest 0.1 teeth, at stated ages of London, Paris, Zurich, and Dakar children.

SUMMARY

Data are presented from samples of London, Paris, Zurich and Dakar children in the first two years of life, born after 1952.

Investigations are made on a coordinated basis and the techniques are the same.

The studies are all longitudinal and incremental data are given. Tables are presented giving comparative data on weight, recumbent-length, skeletal maturity and deciduous tooth eruption.

The European children show very similar patterns of development in all the measurements and are joined in deciduous tooth eruption by the Dakar children. In recumbent-length, weight and skeletal maturity, the Dakar children are born more advanced in maturity and this falls off

Possible explanations are given and discussed.

The Dakar children do not show the advance of the female over the male in skeletal maturity up to one year, which is found in European and American samples of children from birth.

until at 1 year to 18 months of age they are less mature in these factors than the European children.

(We are very grateful indeed for the constant support given by the Centre International de l'Enfance, Paris, to our co-ordinated studies and for their sponsorship of the regular meetings of the teams. In particular we wish to thank Dr Etienne Berthet, Directeur Général, and Dr Nathalie Masse, Directeur de l'Enseignement. Professeur Robert Debré and Professor Alan Moncrieff have given us, and the whole concept of the coordinated studies, constant encouragement and help.)

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Growing Up in Five Countries:

A Comparison of Data on Weaning, Elimination Training, Age of Walking and IQ in Relation to Social Class from European Longitudinal Studies*

C. B. Hindley

INTRODUCTION

There are two major values of longitudinal studies: (1) for assessing changes during development in individuals and in groups; (2) that as their data are collected at frequent intervals they often provide more satisfactory information, even for topics which could in principle be investigated by more economical methods; this is especially true in cases where reliance would otherwise have to be placed on retrospective data, often collected long after the events in question.

Of the following examples, those concerning maternal methods and age of walking could be, and often have been, studied by means of retrospective data. The other example concerning the relationship between earlier and later abilities can only be studied by longitudinal methods.

Comparison of results from different longitudinal studies is obviously highly desirable, and among the more important reasons for doing so are:

1. *To discover the generality of conclusions about development.* Do they depend on the specific social and cultural features of a given sample, or on the particular methods of investigation used? Discrepant results are likely to lead to further knowledge by forcing an examination of the factors related to them.

2. *To test theories about the effects of different cultural backgrounds on development.* This may concern the effects of the provision of certain material objects, such as manipulable toys, on the development of ability, or the influence of different child-rearing practices and attitudes on personality development.

In practice it is very difficult to be sure that information from different workers in different places is strictly comparable. At the simplest level, criteria for walking can differ slightly, with a consequent effect on results, and different criteria of how frequent bed-wetting must be to constitute "enuresis" make many comparisons of different studies almost impossible. At the level of intelligence testing, there are considerable difficulties. In the extreme case a particular intelligence test may have no meaning for a sample of children in a primitive culture, and even in advanced countries the difficulty of test items will differ somewhat according to the locality. However, personality characteristics are the most difficult to compare. "Markedly aggressive behaviour" in one culture may be regarded as the norm in another, and the meaning of particular kinds of response to personality tests may differ in different cultures.

These difficulties can be reduced if workers in different countries agree to adopt the same methods and criteria, as has been done in the studies co-ordinated by the *Centre International de l'Enfance* (Hindley 1960 *a*, *b*), but many difficulties remain.

Fortunately, many can be avoided if comparisons are focused, not so much on absolute differences between samples—except when the information is of a fairly objective kind—but rather on the inter-relationships among data obtained *within* samples (Hindley 1960 *a*). Thus the finding that IQ's tend to be related to social class measures *within* many different samples is more significant than the finding that mean scores may differ *between* them. The factors of different criteria, different item difficulty and different cultural background are all reduced in importance.

The problem of comparing development in different samples immediately involves the question of what parameters to employ. Those presented here are of a relatively simple kind, but in many instances the problems are much more complex and will demand much more sophisticated methods in the future. Bloom (1964) makes some valuable suggestions.

Analysis of Curves of Age of Attainment of Stages in Maternal Handling

Data from five European longitudinal samples, from Brussels, London, Paris, Stockholm and Zurich, have been examined with the co-operation of colleagues and the help of the *Centre International de l'Enfance* (Hindley *et al.* 1965). Data were collected according to a common base-line of methods (Hindley 1960 *b*). Social class was assessed by means of an index combining parental occupation, education, source of revenue and quality of dwelling (Graffar 1960 *a*, *b*, Hindley *et al.* 1965).

Age of Weaning from Breast

The age at which the last breast-feed was given was used as the criterion. Fig. 1 shows big differences both in the percentage of children who were ever breast-fed in the different samples and in the duration of breast-feeding. In the Brussels sample 23 per cent were bottle-

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Based on a paper given to the XVIII International Congress of Psychology, Moscow, 1966.

* We acknowledge the cooperation of the Editors of Spastics International Medical Publications who granted the permission to reproduce this paper first appeared in Develop. Med. Child Neurol. 1968, 10, 715-724.

fed from birth, compared with 0.5 per cent in the Stockholm sample; the median age of weaning in the Brussels sample was 0.9 months compared with 4.5 months in the Stockholm sample at the other extreme. There was no inevitable correspondence between the numbers who started breast-feeding and the numbers who continued. The London sample was highest in the initial incidence of breast-feeding but the curve soon fell to a similar level to that of the Paris sample. This may reflect a discrepancy between the efforts of midwives to encourage breast-feeding and the extent of the mothers' desires to do so.

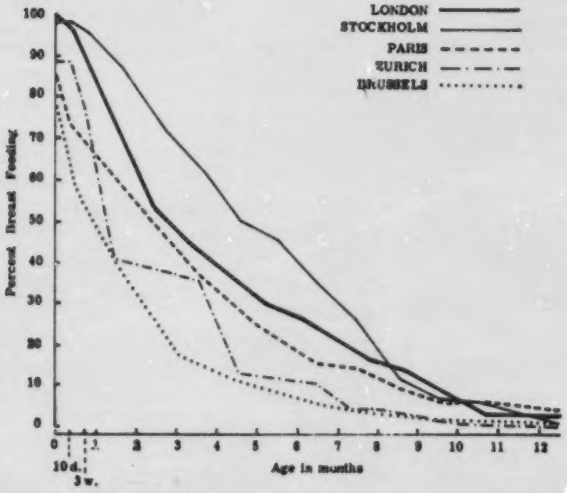

Fig. 1. Duration of breast-feeding in the five samples: percentage still using breast at each age (Hindley *et al.* 1965). Each curve differs significantly from every other ($P < 0.001$, Kolmogorov-Smirnov test).

A further important point is that age of weaning was significantly related to social class in two of the samples, Stockholm (X^2 19.08, d.f. 10, $p < 0.05$) and Zurich (X^2 20.95, d.f. 4, $p < 0.01$), where mothers of higher social class breast-fed longer, but this did not apply in the other three samples. Thus a particular practice may or may not be related to the complex of variables subsumed under the heading of "social class", depending on the particular society.

Behind the differences in the curves there is a general similarity of shape. After an initial rapid fall there tends to be a levelling out to a steadier rate of weaning. For further examination, the curves were plotted on normal probability (probit) paper, which makes a cumulative normal distribution appear as a straight line (Finney 1952). In Fig. 2 it is evident that from ages ranging from 1 to 2½ months the curves assume a roughly straight line form in the different samples, which suggests that from this stage we are dealing with part of a normal distribution curve. Clearly the initial parts of the curves do not conform to this but they also assume a linear form on probit paper when plotted against the logarithm of age.

The overall curves thus appear to embody two components: one applying to the early period, in which the function is normally distributed against the logarithm of age, and the second applying to the later period, which is normally distributed directly against age. The first component would plausibly represent a tendency to wean which is at a maximum in the early weeks and then diminishes. The strength of this tendency could be regarded as the resultant of the strength of the mother's wish to breast-feed, of the infant's response, and of any physiological difficulties encountered. The second component would presumably represent a tendency to wean among cases of established breast-feeding (Hindley *et al.* 1965).

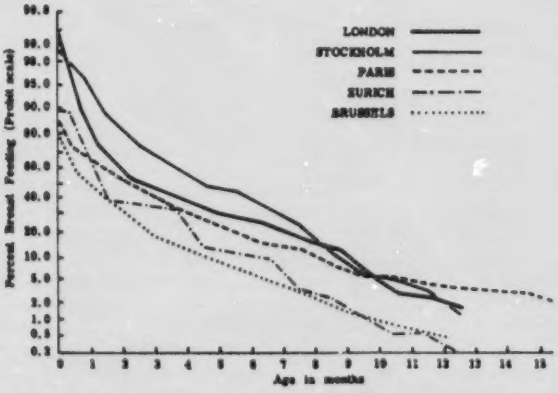

Fig. 2. Percentage still breast-feeding at each age, plotted on a probit scale of percentages (Hindley *et al.* 1965). Key as in Fig. 1.

Age of Weaning from Bottle

The bottle was used at some time by most of the children. The lowest incidence was in the Stockholm sample (79 per cent). In the other three samples considered it was used by 94 per cent or more. Curves of incidence of the use of the bottle at different ages (among those using it) show considerable similarity in form (Fig. 3), although they all differ significantly from each other. A suspicion that they are following some fairly simple ogive function is confirmed by a plot of incidence against the logarithm of age on probit paper.

Why these curves should conform to a function normally distributed against the logarithm of age, when the major parts of the curves for weaning from the breast are distributed against age, is a matter for speculation. It is interesting here that only one component need be postulated. This may well reflect the lack of difficulty in establishing bottle feeding, so that the curves simply represent the weaning process among established bottle-feeders.

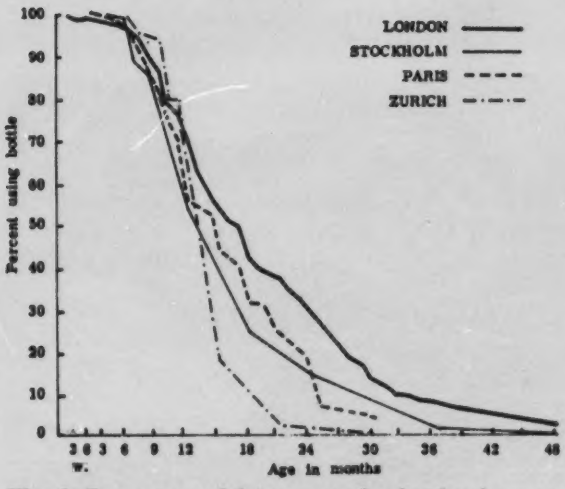

Fig. 3. Percentage of those ever using bottle who were still using it at each age (Hindley *et al.* 1965). All differences between curves were significant ($P < 0.025$ or less, Kolmogorov-Smirnov test), except Paris *v.* Stockholm. Key as in Fig. 1.

In contrast to breast-feeding there was no association in any of the samples between the duration of bottle-feeding and social class (Hindley *et al.* 1965). The relationship between the mothers' readiness to continue giving the oral gratification of the bottle and the duration of breast-feeding is not simple. The Zurich sample stands out as the one in which mothers terminate both breast and bottle soonest. However, mothers in the London sample seemed more prepared to continue bottle-feeding than the Stockholm mothers, though the latter breast-fed much longer.

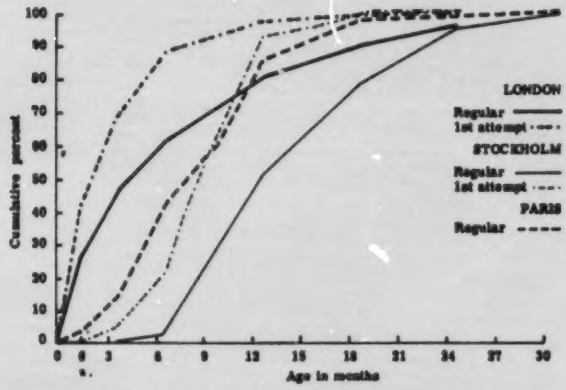

Fig. 4. Age of first attempts and of starting regular elimination training (Hindley *et al.* 1965). First attempts: London *v.* Stockholm ($P < 0.001$, Kolmogorov-Smirnov); regular training: all differences ($P < 0.001$, Kolmogorov-Smirnov).

Start of Elimination Training

Information for first attempts at training is available for two samples, and for the start of regular training (at least daily and not abandoned subsequently) for three samples (fig. 4). Despite large differences between the samples (the median age of regular training ranged from 4.6 in the London sample to 12.4 months in the Stockholm sample), a plot on probit paper against the logarithm of age again suggested roughly normal distributions, especially in the regular training curves of the London and Stockholm samples (Fig. 5). That of the Paris sample is more doubtful.

There were no significant social class differences for the beginning of regular training. However, in the London sample mothers of higher social classes were more likely to make their first attempts at training at a later age (Hindley *et al.* 1965).

While there are wide differences in the ages of starting or finishing the various practices in the three examples considered, the forms of the distributions show considerable similarity among the samples for a particular practice.

Different practices show different incidence curves. Some practices are associated with social class in some samples but not in others. There is also no clear pattern of indulgence towards the child. The London sample start toilet-training very early but are indulgent in their use of the bottle. Thus it may be concluded that mothers' patterns of child rearing vary in complex rather than simple ways from one culture to another.

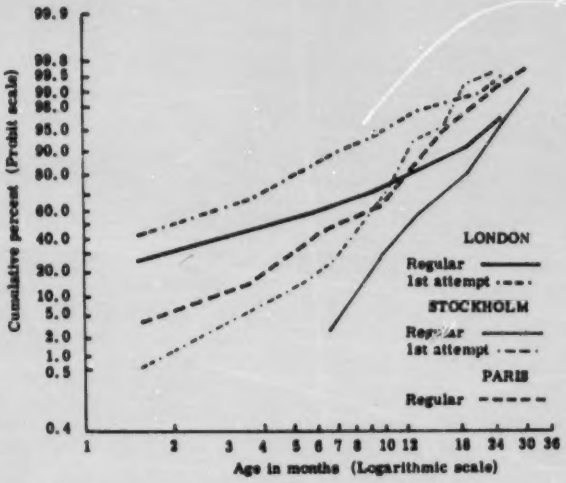

Fig. 5. Ages of starting elimination training plotted on probit scale of incidence against logarithmic scale of age (Hindley *et al.* 1965). Key as in Fig. 4.

Age of Infants' Attainment of Milestones

The only milestone for which data are at present available for the five samples is that of walking unaided (Fig. 6, Hindley *et al.* 1966). Previous work, particular-

ly that of Smith *et al.* (1930), suggested that curves of age of walking were not normal but skewed towards the younger ages. In the present studies a plot of incidence against the logarithm of age on probit paper yields virtually straight lines except at the top of the curves (Fig. 7). The function therefore seems to be approximately normally distributed against the logarithm of age, rather than against age, as was also the case with the onset of several maternal practices.

There seems to be a small group of late walkers who do not conform to the normal distribution, which provides some support for the view of Smith *et al.* (1930) that those walking later than 22 months should be regarded as a special group.

While the five distributions are very similar in form for most of their lengths, it is interesting to find significant differences between the samples in mean ages of starting to walk (Fig. 6), and also in the within-sample variances.

Within-sample analyses of variance revealed no significant social class effects in any of the samples, nor were there any significant sex differences. Why the Stockholm and Brussels children should walk sooner than the others is a matter for further investigation. Williams and Scott (1953) suggested that maternal methods and attitudes might be a factor, or the difference may be associated with the more advanced physical stature of the two samples at 12 months (Graffar *et al.* 1965).

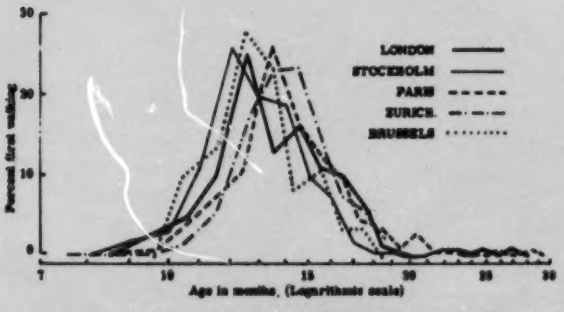

Fig. 6. Age of first walking in the five samples (Hindley *et al.* 1966). Analysis of variance showed the five means to differ significantly more than by chance expectation ($P < 0.001$). Stockholm and Brussels each differed significantly from the other three means ($P < 0.001$, t tests); London differed significantly from Paris ($P < 0.05$, t test). Key as in Fig. 1.

Study of Rising and Falling DQs and IQs

The method of fitting linear curves to each child's DQ and IQ from 6 months to 5 years was applied to the London sample (Hindley 1962, Hindley and Simpson, to be published) and revealed significant tendencies for children in the upper class groups to have rising regression lines with age, and those of lower social class groups to have falling regression lines (Fig. 8). The

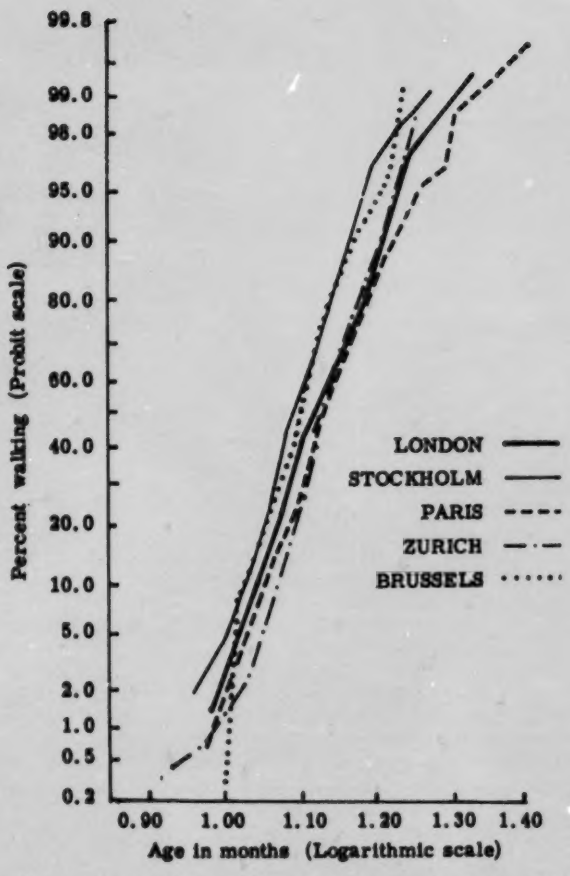

Fig. 7. Percentage walking at each age: cumulative frequency on probit scale, age on logarithmic scale (Hindley *et al.* 1966). Although the curves approximate to straight lines over most of their length, suggesting normal distributions, the departures—especially at the later ages—are such that the hypothesis of normality can only be accepted for the Stockholm and Zurich samples. (Stockholm: X^2 8.52, d. f. 5, $P > 0.10$; Zurich: X^2 3.87, d. f. 6, $P > 0.50$). Key as in Fig. 1.

divergence is of substantial proportions with the upper social class group, showing a mean gain of 1σ (17.6 IQ points) and the lowest group a fall of 0.6σ (10 IQ points) by 5 years of age.

The same tendency has been found up to 3 years of age in the Stockholm sample of Klackenberg-Larsson and Stenson (1964), who also found that other indices of relatively unfavourable family circumstances were associated with falling curves. Sand (1964) obtained similar results in his Brussels sample.

It can be argued that these curves are somewhat misleading in that the abilities measured in the early months are different from those measured later. The

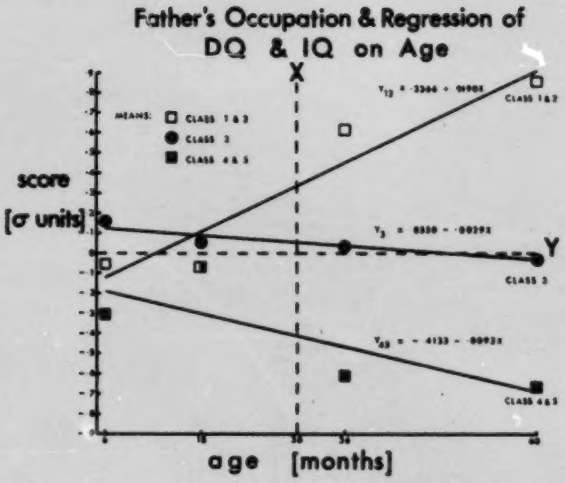

Fig. 8. Regression of DQ and IQ on age in three social class groups, according to father's occupation. The curves represent the best-fitting straight lines to the scores of each group at the four ages: 6 months, 18 months, 3 years, 5 years. The average score of the whole group at each age is portrayed as = 0. Positive or negative deviations from these means are given in standard deviation ( ) units. At age 5 years a score of + 1.0σ is 17.6 IQ points above the sample average. The slope for classes 1 and 2 is significantly rising ($P < 0.001$), and that for classes 4 and 5 is significantly falling ($P < 0.05$) (Hindley 1961).

method would be freer of this criticism if it were applied to factor scores. However, there are positive correlations between scores on the different occasions (Hindley 1965): $r_{6m\text{-}18m} = 0.56$, $r_{18m\text{-}3yr} = 0.54$ even though the latter correlation is between results on the Griffiths Scale of Infant Development on the one hand and the Terman-Merrill on the other. In any event the curves can be regarded as presenting in summary form the trends of scores of different children for further study.

The work of Honzik (1957) and others suggests that the emergence of hereditary differences is one factor likely to be responsible for the social class differences. On the other hand, the findings that the birth of a younger sibling within the first 5 years is significantly associated with falling regression lines, though not the presence of an older sibling, suggests that environmental factors are also likely to be involved (Hindley 1962).

The relationship between the development of abilities in early childhood and social class background has been confirmed in each of the three samples studied, and has also been demonstrated by somewhat different techniques in the American studies of Bayley (1954), Moss and Kagan (1958), Kagan and Moss (1959) and Honzik (1963). It may therefore be taken as a general tendency applicable to various countries and cultures.

CONCLUSIONS

Some caution is needed in comparing results from different longitudinal studies because of the use of different methods and criteria.

It is often more prudent to compare the relationships found *within* different samples.

This may reveal similarities, as in the case of the association of rising IQs with higher social class, or dissimilarities, as in the relationship between breast-feeding and social class.

Despite wide inter-sample differences in maternal practices, the curves of onset and cessation show general similarities of form, as do the curves of age of onset of walking. Comparisons are more revealing when data can be expressed in a similar form, as was shown by Bloom (1964). This helps in the identification of different components in curves of incidence.

When a function changes with some consistency with age in a group, as in the case of IQs in different social class groups, the fitting of curves and a comparison between them gives a more comprehensive picture of changes than the more frequently used correlational techniques.

Acknowledgements: Thanks are due to the International Children's Centre for making possible the collaboration of the five researches, and to the publishers concerned for permission to reproduce the figures.

SUMMARY

The main value of longitudinal studies lies in the assessment of individual changes during development. Moreover, much of the information is more accurate than in retrospective studies. International comparisons of results clarify the generality of findings, and enable hypotheses to be tested about the effects on development of different cultural factors.

Methodological difficulties of such comparisons are discussed, and it is concluded that it is often desirable to compare relationships found between variables within each sample, rather than the basic data.

Findings from five European studies, co-ordinated by the International Children's Centre, are reviewed. Wide differences are found in the duration and incidence of breast-feeding, in some samples associated with social class, but not in others. Use of the bottle varies, and is not closely related to duration of breast-feeding. Wide differences are reported in the age of starting elimination training. Despite the differences between the samples, there are underlying similarities in the distributions.

Significant differences in age of walking were found between the samples, but there were no significant sex or social class differences. The curves of age of onset are roughly normally distributed against the logarithm of age.

In 3 of the samples, as the children grow older an increasing relationship between abilities and social class has been found in the pre-school years. Possible reasons are discussed.

Attention is drawn to the desirability of finding parameters which best display relationships among data.

RÉSUMÉ

Etude de la croissance dans cinq pays; étude comparative du sevrage, de l'éducation de la propreté sphinctérienne, de l'âge de la marche et du QI selon la classe sociale, d'après des études longitudinales en pays européens

L'intérêt principal des études longitudinales réside dans l'évaluation des changements individuels au cours du développement. De plus la plupart des informations sont plus précises que dans les études rétrospectives. La comparaison de résultats obtenus dans des pays différents éclaire leur généralité et permet de mettre à l'épreuve des hypothèses sur les effets de différents facteurs culturels sur le développement.

Des difficultés méthodologiques de telles comparaisons sont discutées et l'on arrive à la conclusion qu'il est souvent préférable de comparer les corrélations obtenues à l'intérieur de chaque échantillon, plutôt que les résultats bruts eux-mêmes.

Une revue est faite des données fournies par cinq études européennes coordonnées par le Centre International de l'Enfance. On a pu ainsi observer des différences importantes dans la durée et la fréquence de l'allaitement maternel, reliées dans certains échantillons à la classe sociale, dans d'autres non. L'usage du biberon varie, et il n'est pas toujours étroitement lié à la durée de l'allaitement maternel. On observe de très grosses différences dans l'âge du début de l'éducation de la propreté. Malgré les différences entre les échantillons, on retrouve des similitudes frappantes dans les distributions.

Une différence significative dans l'âge de la marche a pu être notée dans les différents échantillons, mais il n'y avait pas de différence significative en fonction du sexe ou de la classe sociale. Les courbes représentant l'âge du début de la marche sont normalement distribuées en fonction du logarithme de l'âge.

Dans trois échantillons, on a pu noter une corrélation croissante entre aptitudes et classe sociale avant l'âge scolaire au fur et à mesure que les enfants grandissent. Plusieurs causes possibles sont discutées.

Il demeure qu'il serait souhaitable d'établir des paramètres qui mettraient mieux en évidence les corrélations recueillies.

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L'évolution de l'épaisseur du tissu cellulaire sous-cutané chez l'enfant normal, de la naissance à 3 ans *

Par le Dr Jacqueline CORBIER, Centre National d'Etude de la Croissance et Laboratoire de Médecine Sociale de l'Université Libre de Bruxelles (directeur: Prof. M. GRAFFAR)

CHOIX DES MENSURATIONS

Introduction

On s'est souvent demandé si dans la petite enfance il existait une relation entre la croissance et la quantité de graisse accumulée, autrement dit entre la taille et l'épaisseur du tissu cellulaire sous-cutané.

Un deuxième problème auquel de nombreux auteurs se sont attachés est de savoir si, au cours de la surveillance régulière de la croissance, telle qu'elle est pratiquée dans les consultations de nourrissons, à l'école et au cabinet médical, un paramètre tel que l'épaisseur du tissu cellulaire sous-cutané était susceptible d'apporter au médecin des renseignements complémentaires quant au développement de l'enfant. Etant donné que le poids dépend des dimensions squelettiques, et que le tissu cellulaire sous-cutané en est beaucoup plus indépendant, ce dernier semblerait donc susceptible de fournir plus de renseignements sur l'état de nutrition que ne le fait le poids.

Dans les pages qui suivent, nous avons abordé le problème de l'épaisseur du tissu cellulaire sous-cutané, principalement en le décrivant, sans toutefois chercher à expliquer les phénomènes observés, par ailleurs souvent fort complexes.

Avant toute chose, nous nous sommes demandé en quel endroit il serait le plus judicieux de pratiquer les mesures, c'est-à-dire quel endroit pouvait être considéré comme le plus représentatif de la répartition totale du tissu cellulaire sous-cutané.

Le fœtus humain, maigre pendant les sept derniers mois, se met à accumuler du tissu cellulaire sous-cutané au cours des dernières semaines de sa vie prénatale, jusqu'environ 6 mois après sa naissance.

Garn et Harper ont montré que l'enfant de 1 an avait un taux de graisse proportionnellement semblable à celui d'un adulte de 50 ans et que dans de nombreux cas, la graisse représentait plus de 25 pour cent du poids corporel (Garn, 1956 a).

Il semblerait que cette extraordinaire adiposité du bébé relève d'une adaptation aux problèmes posés par la thermorégulation. Quoique cette interprétation ne puisse évidemment pas se vérifier directement, on doit admettre qu'une adaptation à de basses températures se réalise plus aisément en présence d'une couche de tissu cellulaire sous-cutané adéquate. D'autre part, l'expérience a prouvé que cette épaisseur de graisse réduit les pertes de chaleur chez le tout petit et de ce fait minimise la demande calorique (Garn, 1956 a).

On sait qu'un changement de poids est souvent dû à un gain ou à une perte de graisse. Le tissu cellulaire sous-cutané semble donc pouvoir donner une indication de la balance existant entre l'apport et la perte calorique.

Chez l'adulte, une grande partie de la graisse accumulée est utilisable lorsque besoin s'en fait sentir.

Il est prouvé qu'au cours de la moyenne et de la grande enfance, l'accumulation de graisse est directement en relation avec l'augmentation de taille et de poids (Bruch, Fry, cités par Garn, 1956 a). Les enfants plus gras ont tendance à être un peu plus grands, un peu plus précoces en ce qui concerne la maturation squelettique, dentaire et sexuelle que les autres; ils ont également tendance à avoir une excrétion urinaire de 17 cétostéroïdes supérieure à la moyenne pour leur âge (Talbot, Sobel, MacArthur, Crawford, cités par Garn, 1956 a).

Connaissant ces faits, il serait intéressant de savoir quelle est la situation pour la petite enfance.

Méthodologie

Les résultats que nous présentons ont été obtenus sur un groupe d'enfants suivis selon la méthode longitudinale et recrutés au moment de la naissance parmi les habitants de la commune de St-Gilles à Bruxelles. Celle-ci a été choisie en raison de son caractère représentatif de la répartition des classes sociales de l'agglomération bruxelloise.

Le recrutement de ces enfants s'est poursuivi d'avril 1955 à juin 1958. Toutes les mères qui ont mis au monde un bébé d'un poids supérieur à 2 kg 500, sans malformation cliniquement décelable, ont été invitées à présenter leur enfant au Centre. Les examens ont eu lieu à 4, 13, 26, 39, 52 semaines et à 18 mois, ensuite une fois par an au moment de l'anniversaire de l'enfant.

N'ont été retenus en vue de l'analyse que les examens qui ont eu lieu entre des limites de temps très strictes. C'est pour cette raison que si l'échantillon compte au départ 229 enfants (124 garçons et 105 filles), le nombre des sujets dont les mesures ont été analysées aux différents âges est inférieur à 229 (Graffar, 1960).

* Travail déjà publié dans Biométrie-Praximétrie, 1963, 4, 99-110.

Les écarts de temps tolérés sont respectivement :

Age (en mois)	Ecart toléré (en jours)
1	± 2
3	± 7
6	± 7
9	± 7
12	± 7
18	± 7
24	± 15
36	± 15

Technique de mensuration

Les techniques de mensurations sont celles qui ont été adoptées par les Centres d'Etude de la Croissance dont les recherches sont coordonnées par le Centre International de l'Enfance (Falkner, 1961).

Les mesures sont effectuées dans des conditions standardisées par un examinateur entraîné, à l'aide du compas d'épaisseur de Harpenden. Ce compas consiste en 2 petites plaques rectangulaires plates, de 30 mm² de surface, qui peuvent se rapprocher l'une de l'autre, sous une pression constante de 10 g par mm² fournie par un ressort, la distance entre les plaques étant lue sur un cadran circulaire au 1/10e de mm près. La mesure se fait en 4 points électifs. On saisit entre le pouce et l'index un pli de tissu cellulaire sous-cutané qui est ensuite placé entre les branches du compas. La lecture se fait le plus rapidement possible de façon à exercer la compression la moins longue possible. Les mesures ne sont qu'exceptionnellement douloureuses et l'enfant proteste rarement malgré la force apparente du ressort utilisé.

a) *Biceps :* le pli est pincé au niveau du biceps sur la face antérieure du bras en un point situé à égale distance de l'acromion et de la tête du radius.
b) *Triceps :* le pli est mesuré à la même hauteur que pour le biceps, mais au niveau du triceps, sur la face postérieure du bras.
c) *Sous-scapulaire :* le pli est pincé en un point situé en dessous et en dehors de la pointe de l'omoplate.
d) *Supra-iliaque :* le pli est pincé en un point situé sur la ligne axillaire moyenne, en dessous de la dernière côte et au-dessus de la crête iliaque.

Les auteurs qui se sont attachés au problème de l'épaisseur du tissu cellulaire sous-cutané ont pratiqué les mensurations, par méthode radiographique ou par des compas d'épaisseur de types variés, en de nombreux endroits du corps ; parmi ceux-ci quelques-uns semblent avoir retenu l'attention générale : régions deltoïdienne, supra-iliaque, sous-scapulaire, trochantérienne, régions antérieure, postérieure, interne et externe de la jambe, régions externe et interne de l'avant-bras, régions bicipitale, tricipitale et thoracique inférieure (Garn, 1954).

Edwards a effectué des mesures en 53 endroits différents (mesures qu'il additionne), Richer en 20 endroits, Matiegka en 7, Tehredebrugge en 66, Oeder au niveau abdominal seulement, Batkin au niveau du mamelon et sous l'omoplate (cités par Keys et Brozek, 1953).

Selon Keys et Brozek (1953), de nombreuses mensurations s'imposent si l'on se propose d'étudier les modifications de la répartition graisseuse dans les lipomatoses ou les lipodystrophies ; un nombre plus restreint, mais minimal, suffit si l'on désire simplement déterminer le degré d'adiposité et l'état de nutrition d'un individu normal.

Keys et Brozek (1953) recommandent les mesures au niveau de la région postérieure du bras, sous l'omoplate, au-dessus de la crête iliaque et sur la ligne axillaire, vu que celles-ci présentent une bonne corrélation avec le poids spécifique (r = 0,828).

A Dakar, Geneviève Massé a fixé son choix sur la mensuration au niveau sous-scapulaire : cette épaisseur est peu susceptible d'erreur de la part de l'observateur vu qu'elle varie moins autour du point exact où doit être faite la mesure que les autres emplacements (Massé, 1960).

A Londres, l'équipe de Tanner mesure les épaisseurs du tissu cellulaire sous-cutané au niveau tricipital et sous-scapulaire. Elle estime que ces deux mesures s'avèrent comme un minimum indispensable étant donné les différences importantes existant dans l'évolution du tissu cellulaire sous-cutané au niveau du tronc et des membres. Les raisons du choix se justifient par le fait qu'aux 2 endroits envisagés, l'équipe de Londres parvient à réaliser un pli convenable de peau et de graisse et à effectuer de la sorte une mesure précise (Tanner, 1962).

Selon Hammond, les mensurations au niveau du triceps, de la région sous-scapulaire et ombilicale sont les plus représentatives de la modification totale du tissu cellulaire sous-cutané : elles présentent entre elles une corrélation moyenne de 0,56 (Hammond, 1955).

Toujours selon Hammond, il vaut mieux effectuer des mesures en plusieurs endroits lorsqu'on étudie les modifications de l'épaisseur du tissu cellulaire sous-cutané, alors qu'une seule mesure peut suffire dans les études transversales.

A quel point les résultats obtenus par compas d'épaisseur et par radiographie concordent-ils ?

Comparant ces deux types de mensurations au niveau de la région thoracique inférieure chez 65 adultes masculins de 21-22 ans, Garn (1956 b) trouve un coefficient de corrélation de 0,88. Hammond (1955) obtient de son côté une corrélation de 0,83 au niveau du biceps et de 0,89 au niveau du triceps.

Rappelons que dans les mesures par compas d'épaisseur, on réalise toujours une erreur d'environ 30 % par défaut, due à la compression des tissus par la force exercée par les branches de l'instrument ou par le simple fait de soulever la peau, compression n'intervenant évidemment pas dans les mesures par radiographie, et que d'autre part, le compas d'épaisseur mesure en fait une épaisseur double de tissu cellulaire sous-cutané.

Il est évident par ailleurs que les mensurations par compas d'épaisseur présentent une certaine variabilité

due au manque d'uniformité dans la façon de pincer la peau et de placer le compas (position du compas lui-même et endroit où il est placé), aux modifications de la compressibilité du tissu cellulaire sous-cutané, et aux variations de l'épaisseur de la peau elle-même: un œdème sous-cutané, sous l'influence de la chaleur par exemple, détermine une erreur par excès, tant dans les mesures effectuées par radiographie que par compas (Tanner, 1955).

De toute façon, les inconvénients de la mesure par compas d'épaisseur sont moindres que ceux posés par une radiographie des tissus mous où jouent le temps d'exposition, la difficulté d'interprétation et le coût de la radio.

Lieux de mensuration choisis

Afin de limiter le nombre des opérations statistiques, nous nous sommes demandé quelles mesures minimales seraient les plus représentatives de la répartition du tissu cellulaire sous-cutané.

Nous nous sommes à cet effet basés sur une série de critères:

a) *subjectif*, à savoir la facilité avec laquelle l'observateur effectue la mesure. Il s'est révélé, à l'expérience, que la difficulté de la mensuration était la plus grande au niveau du supra-iliaque, ensuite du triceps, puis du sous-scapulaire, la mensuration au niveau du biceps étant la plus aisée, du moins dans le premier âge.

Retenons toutefois, qu'à mesure que l'enfant grandis, la mensuration au niveau du biceps perd de sa commodité au profit du triceps.

Cette facilité ou difficulté s'explique d'une façon à la fois anatomique et psychologique de la part de l'enfant, ce dernier étant plus ou moins chatouilleux suivant l'endroit envisagé.

b) *statistiques*, c'est-à-dire objectifs:

Mentionnons avant toute chose que le tissu cellulaire sous-cutané présente une distribution asymétrique. Sa courbe de répartition est du même type que celle du poids, c'est-à-dire déviée vers la droite.

L'histogramme de l'épaisseur du tissu cellulaire sous-cutané mesuré au niveau du biceps chez les garçons de 1 mois, en est une illustration. Dans cet histogramme, l'intervalle de classe est de 0,4 mm.

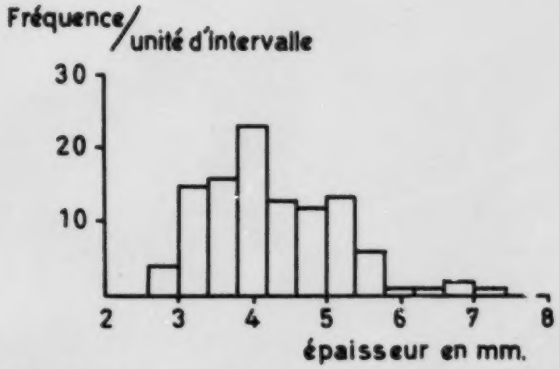

Fig. 1: Histogramme du tissu cellulaire sous-cutané bicipital.

Les critères statistiques que nous avons retenus sont les suivants:

1) *Le coefficient de variabilité.* Les tableaux 1 et 2 en indiquent les valeurs pour les 2 sexes aux différents âges

TABLEAU 1

Coefficients de variation pour les mesures de l'épaisseur du tissu cellulaire sous-cutané chez le garçon aux différents âges considérés

Age	C.V. biceps	C.V. triceps	C.V. sous-scapulaire	C.V. supra-iliaque
1 mois	0,21	0,20	0,23	0,23
3 mois	0,21	0,21	0,24	0,32
6 mois	0,18	0,18	0,22	0,34
9 mois	0,19	0,18	0,27	0,35
12 mois	0,21	0,20	0,25	0,33
18 mois	0,22	0,24	0,25	0,42
24 mois	0,20	0,22	0,22	0,34
36 mois	0,22	0,21	0,27	0,34
C.V. moyen	0,21	0,21	0,24	0,34

TABLEAU 2

Coefficients de variation pour les mesures de l'épaisseur du tissu cellulaire sous-cutané chez la fille aux différents âges considérés

Age	C.V. biceps	C.V. triceps	C.V. sous-scapulaire	C.V. supra-iliaque
1 mois	0,24	0,20	0,23	0,29
3 mois	0,22	0,22	0,21	0,29
6 mois	0,19	0,19	0,22	0,32
9 mois	0,21	0,19	0,22	0,35
12 mois	0,24	0,22	0,24	0,37
18 mois	0,34	0,23	0,26	0,41
24 mois	0,21	0,21	0,23	0,40
36 mois	0,22	0,19	0,24	0,29
C.V. moyen	0,23	0,21	0,23	0,34

envisagés. Quoique la méthode ne soit pas classique, nous avons résumé l'ensemble des coefficients de variation de 1 à 36 mois en une moyenne de coefficients de variation qui n'a qu'une valeur purement arithmétique et non statistique.

2) *Les corrélations* existant entre les différentes mensurations du tissu cellulaire sous-cutané (biceps, triceps, sous-scapulaire, supra-iliaque); ces corrélations ont été déterminées pour les garçons à l'âge d'un mois, un an et 3 ans et figurent au tableau 3.

TABLEAU 3

Coefficients de corrélation existant entre les différentes mesures d'épaisseur de tissu cellulaire sous-cutané chez le garçon de 1 mois

	biceps	triceps	sous-scapulaire	supra-iliaque
biceps	1	0,53	0,47	0,55
triceps	0,53	1	0,56	0,55
sous-scapulaire	0,47	0,56	1	0,68
supra-iliaque	0,55	0,55	0,68	1

Coefficients de corrélation existant entre les différentes mesures d'épaisseur de tissu cellulaire sous-cutané chez le garçon de 12 mois

	biceps	triceps	sous-scapulaire	supra-iliaque
biceps	1	0,53	0,35	0,32
triceps	0,53	1	0,54	0,48
sous-scapulaire	0,35	0,54	1	0,46
supra-iliaque	0,32	0,48	0,46	1

Coefficients de corrélation existant entre les différentes mesures d'épaisseur de tissu cellulaire sous-cutané chez le garçon de 3 ans

	biceps	triceps	sous-scapulaire	supra-iliaque
biceps	1	0,51	0,33	0,36
triceps	0,51	1	0,47	0,40
sous-scapulaire	0,33	0,47	1	0,22
supra-iliaque	0,36	0,40	0,22	1

Ce sont les mesures effectuées au niveau tricipital et sous-scapulaire qui présentent en général la meilleure corrélation avec les autres mesures. Garn avait précédemment montré que les mesures effectuées au niveau des régions dites «de graisse centrale» (telles que les régions deltoïdienne et supra-iliaque par exemple) présentaient entre elles une corrélation supérieure à celle des mesures effectuées au niveau des aires de «graisse périphérique» (triceps, biceps) (Garn, 1957). Nous ne retrouvons pas ce phénomène ici.

3) *La similitude* entre les mensurations pratiquées à droite et celles pratiquées à gauche. Cette dernière a été recherchée chez les garçons et chez les filles à l'âge de 3 ans, étant donné qu'aux autres âges, nous ne possédions pas un nombre suffisant de mesures effectuées à la fois à droite et à gauche (cf. tableau 4).

TABLEAU 4

Comparaison entre les mesures pratiquées à droite et à gauche chez les enfants de 3 ans. Valeurs de *t*

	n	Garçons	*n*	Filles
biceps	71	2,90**	64	2,95**
triceps	71	0,68	64	0,08
sous-scapulaire	71	0,21	64	0,10
supra-iliaque	71	1,75	64	0,80

n = nombre de couples

Il n'existe pas de différence statistiquement significative (déterminée par un test *t* de Student) entre les mesures pratiquées à droite et à gauche pour le triceps et le sous-scapulaire. La différence est significative au seuil de 0.01 pour le biceps.

Selon Edwards, la précision de la mesure dépend essentiellement du fait que certains plis (sous-scapulaire par exemple) sont pincés plus facilement et que leur épaisseur varie moins sur de petites distances que d'autres. De ce dernier point de vue, le biceps et le supra-iliaque offrent le moins de garanties. Les écarts-types des différences existant entre des mesures prises à répétition sont les plus bas pour le triceps et le sous-scapulaire, les plus élevés pour le biceps (Edwards, 1955).

En conclusion, nous voyons donc, si nous reprenons les quatre critères que nous nous étions proposé d'examiner, que la mensuration de l'épaisseur du tissu cellulaire sous-cutané au niveau sous-scapulaire est aisée à pratiquer et peu susceptible d'erreur de la part de l'observateur, qu'il s'agit d'une mesure à faible dispersion et à assez bonnes corrélations. Le triceps, quant à lui, est également peu susceptible d'erreur de la part de l'observateur, il devient plus facile à mesurer avec l'âge et présente d'assez bonnes corrélations avec les autres mesures de tissu cellulaire sous-cutané.

Nous envisagerons par conséquent dans la suite des articles qui paraîtront ultérieurement de limiter l'étude statistique de l'épaisseur du tissu cellulaire sous-cutané aux triceps et sous-scapulaire uniquement. Pour l'étude descriptive, nous continuerons à tenir compte des 4 épaisseurs de tissu graisseux préalablement citées (biceps, triceps, sous-scapulaire, supra-iliaque).

** Existence d'une différence significative au seuil de 0.01.

RÉSUMÉ

L'auteur souligne l'intérêt que présente l'étude de l'épaisseur du tissu cellulaire sous-cutané chez l'enfant.

Il lui paraît souhaitable, pour des raisons de commodité pratique, de limiter autant que possible le nombre de mesures à effectuer.

Il expose les raisons qui lui ont fait donner la préférence aux emplacements sous-scapulaire et tricipital.

SUMMARY

The author underlines the interest that may present the study of fat thickness during the child's first years.

It seems more convenient to her to limit as much as possible the number of measurements.

She explains why she has chosen the sub-scapular and tricipital places.

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L'évolution de l'épaisseur du tissu cellulaire sous-cutané chez l'enfant normal, de la naissance à 3 ans *

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ÉTUDE DESCRIPTIVE DES DONNÉES

Bien que les données concernant la taille et le poids soient incontestablement utiles dans l'étude de la croissance, de l'état de santé et de nutrition de l'enfant, elles sont insuffisantes par elles-mêmes pour pouvoir répondre à d'autres problèmes importants. Par exemple, elles ne montrent pas si un enfant est gras ou mince par rapport à ses compagnons ou par rapport à lui-même considéré à un âge antérieur. Un enfant qui est au-dessus du poids moyen pour sa taille peut être un enfant gras, ou musclé, ou un enfant qui a des os lourds. Inversement, un enfant dont le poids est faible par rapport à sa taille peut être simplement mince ou trop peu musclé, soit avoir des os légers. D'autre part, un gain de poids chez l'enfant ne peut pas être considéré formellement comme un gain de graisse, ainsi qu'il est courant chez l'adulte. Les mesures anthropométriques de poids et de taille gagneraient à être complétées par des mesures du tissu cellulaire sous-cutané. Celui-ci peut être mesuré directement avec une précision satisfaisante en pinçant un pli de peau et de tissu cellulaire sous-cutané au moyen d'un compas spécial, technique que nous avons décrite précédemment (Corbier 1963).

La corrélation entre ce type de mensuration et la mensuration par radiographie est élevée, de l'ordre de 0,85 à 0,90 (Tanner, 1962).

La mesure de l'épaisseur du tissu cellulaire sous-cutané a été largement utilisée au cours des dix dernières années dans la détermination de l'obésité et de la malnutrition chez les enfants et les adultes.

Nous avons par conséquent pensé que nous ferions œuvre utile en préparant, de même que pour le poids et la taille, des données pour l'épaisseur du tissu cellulaire sous-cutané d'un échantillon d'enfants belges normaux.

Les techniques et les lieux de mensuration ont été décrits dans un article antérieur (Corbier, 1963). Rappelons que les observations présentées dans ce travail proviennent d'un groupe d'enfants recruté parmi les habitants de St-Gilles, commune de l'agglomération bruxelloise; cet échantillon a été constitué du 2 avril 1955 au 13 juin 1958 d'enfants nouveau-nés, à terme, normaux, d'un poids de naissance atteignant au moins 2500 grammes, provenant de mères de nationalité belge.

Ces enfants ont été présentés au Centre à 5 reprises au cours de la première année (aux âges de 4, 13, 26, 39 et 52 semaines), à l'âge de 18 mois, ensuite à chaque anniversaire. Les écarts tolérés en deçà et au-delà de la date prévue pour l'examen sont les suivants:

Ages en mois	Ages en semaines	Ecart toléré
1	4	2 jours
3	13	1 semaine
6	26	1 semaine
9	39	1 semaine
12	52	1 semaine
18	78	1 semaine
24	104	2 semaines
ensuite une fois par an (Graffar, 1961)		2 semaines

L'échantillon se composait au départ de 229 enfants (124 garçons et 105 filles). Toutefois, le nombre de sujets dont les mesures ont été analysées aux différents âges est inférieur à 229, en raison d'abandons ou de présences à des dates incorrectes.

Les mesures du tissu cellulaire sous-cutané ont été pratiquées en quatre endroits (biceps, triceps, sous-scapulaire, supra-iliaque), du côté gauche, par tradition anthropométrique.

La précision de la lecture est assez grande: en répétant ses mesures, un observateur entraîné constate que ses erreurs ne dépassent pas 5 pour cent. En comparant des mesures effectuées par des opérateurs différents, on peut observer des erreurs de l'ordre de 10 pour cent; ceci est dû au fait qu'il existe des différences individuelles dans la façon de pincer la peau.

1. Evolution des moyennes de l'épaisseur du tissu cellulaire sous-cutané

L'épaisseur du tissu cellulaire sous-cutané ne se distribue pas selon une courbe gaussienne: sa distribution est de même type que celle du poids; il s'agit d'une courbe déviée vers la droite (*cf.* un histogramme paru dans un article antérieur - Corbier, 1963). La notion d'écart-étalon n'est donc pas applicable au cas qui nous occupe. Cependant, à titre purement indicatif, nous avons calculé les moyennes et écarts-étalons de 1 à 36 mois au niveau: a) du biceps
b) du triceps
c) du sous-scapulaire
d) du supra-iliaque
(*cf.* tableau 1 (a, b, c, d)

* Travail déjà publié dans Biométrie-Praximétrie, 1963, 3, 165-184.

TABLEAU 1

Evolution des moyennes de l'épaisseur du tissu cellulaire sous-cutané chez le garçon et la fille de 1 mois à 3 ans

Age	Garçons			Filles		
	Nombre de cas	Moyenne en mm	Ecart-type en mm	Nombre de cas	X	σ
1 mois	108	4,37	0,90	95	4,40	1,04
3 mois	113	5,77	1,23	94	6,05	1,32
6 mois	114	6,74	1,18	100	6,70	1,29
9 mois	105	6,43	1,22	91	6,40	1,32
12 mois	105	6,00	1,28	90	6,30	1,53
18 mois	103	5,98	1,34	85	6,09	1,58
2 ans	99	5,69	1,11	86	6,02	1,26
3 ans	98	5,46	1,19	83	5,48	1,20

a) *Tissu cellulaire sous-cutané du biceps*

Age	Garçons			Filles		
	Nombre de cas	Moyenne en mm	Ecart-type en mm	Nombre de cas	X	σ
1 mois	108	6,20	1,25	95	6,60	1,33
3 mois	113	8,83	1,86	94	8,90	1,92
6 mois	114	10,40	1,86	100	10,80	2,06
9 mois	105	10,70	1,94	91	11,00	2,14
12 mois	105	10,80	2,17	90	10,90	2,32
18 mois	103	10,68	2,60	85	11,67	2,62
2 ans	99	10,66	2,35	86	11,44	2,41
3 ans	98	9,67	2,06	83	10,66	1,98

b) *Tissu cellulaire sous-cutané du triceps*

Age	Garçons			Filles		
	Nombre de cas	Moyenne en mm	Ecart-type en mm	Nombre de cas	X	σ
1 mois	108	5,83	1,32	95	6,30	1,46
3 mois	113	7,27	1,75	94	7,70	1,63
6 mois	114	7,40	1,60	100	8,03	1,79
9 mois	105	7,40	2,00	91	8,20	1,82
12 mois	105	8,00	2,03	90	8,40	2,02
18 mois	103	7,56	1,78	85	8,22	1,98
2 ans	99	7,30	1,60	86	7,98	1,85
3 ans	98	6,25	1,70	83	7,32	1,76

c) *Tissu cellulaire sous-cutané sous-scapulaire*

Age	Garçons			Filles		
	Nombre de cas	Moyenne en mm	Ecart-type en mm	Nombre de cas	X	σ
1 mois	108	4,48	1,03	95	4,90	1,41
3 mois	113	7,01	2,22	94	7,70	2,26
6 mois	114	8,90	2,99	100	9,10	2,94
9 mois	105	8,30	2,92	91	8,90	3,15
12 mois	105	7,80	2,61	90	9,20	3,45
18 mois	103	7,67	3,19	85	8,78	3,52
2 ans	99	7,25	2,44	86	8,82	3,53
3 ans	98	6,72	2,26	83	8,00	2,30

d) *Tissu cellulaire sous-cutané supra-iliaque*

On remarque que les épaisseurs moyennes de tissu cellulaire sous-cutané des filles sont généralement supérieures à celles des garçons. La différence entre les deux sexes est significative au seuil de 0,01 aux âges de 1, 6, 9, 24 et 36 mois, au seuil de 0,05 à 3 et 18 mois (*cf.* tableau 2 a).

TABLEAU 2 a

Validité de la différence d'épaisseur de tissu cellulaire sous-cutané entre le garçon et la fille

Age	Valeurs de *t*
1 mois	2,70**
3 mois	2,55*
6 mois	2,58**
9 mois	2,96**
12 mois	1,68
18 mois	2,44*
2 ans	2,83**
3 ans	4,28**

* : différence statistiquement significative au seuil de 0,05.
** : différence statistiquement significative au seuil de 0,01.

Rappelons qu'un seuil de 0,05 signifie que les valeurs de *t* réservent moins de 5 chances sur cent ($P < 0,05$) pour que les différences observées soient l'effet du hasard.

Nous avons calculé pour chaque enfant et à chaque âge le rapport entre la valeur de l'épaisseur du tissu cellulaire sous-cutané mesurée au niveau du biceps et la valeur du poids, et calculé ensuite à partir de ces rapports individuels le rapport moyen, d'une part pour les filles, d'autre part pour les garçons, à chacun des âges considérés. Ce rapport est plus élevé chez les filles que chez les garçons; autrement dit, le dépôt adipeux est, proportionnellement au poids, plus important chez le bébé féminin, phénomène bien connu chez la femme adulte (Garn, 1958). La différence entre filles et garçons est statistiquement significative au seuil de 0,01 aux âges de 3, 12 et 24 mois et au seuil de 0,05 à l'âge de 1 mois (*cf.* tableau 2 b).

TABLEAU 2 b

Valeurs du rapport graisse (tissu cellulaire sous-cutané du biceps)/poids chez les garçons et chez les filles de 1 mois à 3 ans

Age	Filles	Garçons
1 mois	1,16*	1,09*
3 mois	1,09**	0,98**
6 mois	0,90	0,85
9 mois	0,72	0,69
12 mois	0,65**	0,58**
18 mois	0,54	0,52
2 ans	0,49**	0,45**
3 ans	0,38	0,37

Pas d'astérisque : pas de différence statistiquement significative.
* : différence statistiquement significative au seuil 0,05.
** : différence statistiquement significative au seuil 0,01.

2. Evolution des percentiles de l'épaisseur du tissu cellulaire sous-cutané

Du fait du caractère asymétrique de la distribution de l'épaisseur du tissu cellulaire sous-cutané, il est préféra-

ble pour comparer la mesure du tissu graisseux d'un enfant déterminé à celles des enfants de même âge de la population générale, d'utiliser les percentiles plutôt que les moyennes et écarts-étalons. Nous avons par conséquent jugé nécessaire de calculer la distribution de notre échantillon en percentiles dont nous avons choisi les suivants: 3, 10, 50, 90, 97.

Dans le cas qui nous occupe d'une distribution non gaussienne, le percentile 50 ne coïncide pas avec la moyenne. Entre les percentiles 10 et 90, se trouvent 80 pour cent des enfants. Au-delà du percentile 97 et en deçà du percentile 3 se situent les 6 pour cent extrêmes de la population.

Nous avons calculé une première fois les percentiles en tenant compte des mesures de tous les sujets observés (méthode transversale). Nous avons recommencé les calculs en suivant une méthode longitudinale pure et en ne retenant que les mesures des sujets qui étaient présents à l'examen à l'âge considéré et également aux âges immédiatement antérieur et postérieur (sauf bien entendu pour les âges de 1 mois et 3 ans où nous avons considéré comme cas longitudinaux purs les sujets examinés respectivement à 1 et 3 mois ou à 2 et 3 ans).

Nous avons ainsi obtenu 40 paires de mesures (les cinq percentiles choisis: 3, 10, 50, 90, 97, à huit âges différents: 1, 3, 6, 9, 12, 18, 24, 36 mois). En comparant ces paramètres deux à deux, nous n'avons enregistré une différence de plus de 0,2 mm que dans six cas (la plus grande différence notée étant de l'ordre de 6 pour cent). Le seuil d'appréciation des différences entre les deux méthodes a été fixé à 0,2 mm, en raison du fait que le compas d'épaisseur est gradué en 0,2 mm (*cf.* tableau 3).

TABLEAU 3

Comparaison des percentiles d'épaisseur de tissu cellulaire sous-cutané mesuré chez le garçon au niveau sous-scapulaire suivant la méthode transversale et la méthode longitudinale

Age	Percentiles suivant la méthode transversale					
	3	10	50	90	97	Nombre de cas
1 mois	3,7	4,3	5,5	7,4	9,0	108
3 mois	4,7	5,4	7,0	9,2	9,9	113
6 mois	5,0	5,7	7,1	9,7	10,9	114
9 mois	4,8	5,4	7,2	9,9	11,0	103
12 mois	5,0	5,4	7,7	10,7	11,6	105
18 mois	4,8	5,4	7,3	9,3	11,2	103
24 mois	4,8	5,3	7,2	9,3	10,0	99
36 mois	4,0	4,5	6,0	8,0	10,0	96

Age	Percentiles suivant la méthode longitudinale					
	3	10	50	90	97	Nombre de cas
1 mois	3,6	4,1	5,5	7,6	9,0	100
3 mois	4,6	5,4	6,9	9,2	9,6	93
6 mois	4,7	5,6	7,0	9,6	10,9	89
9 mois	4,8	5,3	7,1	9,5	10,9	84
12 mois	4,9	5,3	7,5	10,5	12,0	75
18 mois	4,9	5,5	7,3	9,2	11,2	82
24 mois	4,7	5,2	7,0	9,2	9,6	82
36 mois	3,9	4,4	5,9	7,9	9,7	91

TABLEAU 4a

Percentiles d'épaisseur de tissu cellulaire sous-cutané

Age	Percentiles	Garçons		Filles	
		N	TCSC en mm	N	TCSC en mm
1 mois	3	108	2,92	95	2,86
	10		3,24		3,10
	50		4,15		4,38
	90		5,41		5,82
	97		6,55		6,22
3 mois	3	113	3,28	94	3,96
	10		3,97		4,38
	50		5,68		5,80
	90		7,17		7,76
	97		8,12		9,04
6 mois	3	114	4,81	100	4,20
	10		5,07		5,15
	50		6,73		6,77
	90		8,11		8,30
	97		8,98		9,20
9 mois	3	105	4,02	91	4,57
	10		4,86		4,96
	50		6,50		6,30
	90		7,83		8,06
	97		8,89		9,13
12 mois	3	105	4,21	90	3,97
	10		4,50		4,80
	50		5,77		6,23
	90		7,65		8,05
	97		9,29		8,69
18 mois	3	103	4,15	85	3,88
	10		4,80		4,24
	50		5,55		5,65
	90		7,50		8,24
	97		9,15		9,50
24 mois	3	99	3,90	86	4,10
	10		4,40		4,80
	50		5,55		5,80
	90		7,25		7,30
	97		7,95		8,90
36 mois	3	96	3,60	83	3,40
	10		4,15		4,05
	50		5,25		5,10
	90		7,10		7,05
	97		8,40		8,10

a) *Tissu cellulaire sous-cutané du biceps*

TABLEAU 4b

Percentiles d'épaisseur de tissu cellulaire sous-cutané

Age	Percentiles	Garçons		Filles	
		N	TCSC en mm	N	TCSC en mm
1 mois	3	108	4,25	95	4,64
	10		4,75		4,98
	50		5,94		6,70
	90		7,91		8,33
	97		8,68		9,16
3 mois	3	113	5,08	94	5,85
	10		6,81		6,24
	50		8,81		8,87
	90		10,91		11,18
	97		11,92		12,64
6 mois	3	114	7,28	100	7,40
	10		8,04		8,27
	50		10,26		10,60
	90		12,90		13,60
	97		13,72		14,90
9 mois	3	105	7,32	91	6,95
	10		8,10		8,62
	50		10,82		10,96
	90		13,45		13,78
	97		14,17		15,25
12 mois	3	105	7,43	90	7,07
	10		8,65		7,80
	50		10,38		10,95
	90		14,75		13,80
	97		15,34		15,66
18 mois	3	103	6,00	85	6,92
	10		7,40		8,82
	50		10,30		11,65
	90		13,70		14,83
	97		15,40		17,70
24 mois	3	99	6,70	86	7,70
	10		8,00		9,00
	50		10,20		11,00
	90		13,85		14,55
	97		15,90		17,00
36 mois	3	96	6,50	83	7,50
	10		7,00		8,40
	50		9,60		10,40
	90		13,00		13,30
	97		13,70		14,50

b) *Tissu cellulaire sous-cutané du triceps*

TABLEAU 4c

Percentiles d'épaisseur de tissu cellulaire sous-cutané

Age	Percentiles	Garçons		Filles	
		N	TCSC en mm	N	TCSC en mm
1 mois	3	108	3,68	95	3,97
	10		4,25		4,62
	50		5,54		6,30
	90		7,44		8,50
	97		8,98		9,63
3 mois	3	113	4,68	94	5,08
	10		5,35		5,48
	50		6,97		7,53
	90		9,19		9,76
	97		9,86		11,02
6 mois	3	114	5,03	100	5,45
	10		5,66		5,80
	50		7,13		7,83
	90		9,72		10,20
	97		10,90		12,70
9 mois	3	103	4,81	91	5,35
	10		5,35		6,21
	50		7,22		7,78
	90		9,87		10,90
	97		10,99		12,05
12 mois	3	105	5,01	90	5,94
	10		5,43		6,35
	50		7,68		8,15
	90		10,70		11,10
	97		11,57		12,33
18 mois	3	103	4,81	84	5,10
	10		5,42		5,89
	50		7,32		7,90
	90		9,27		11,10
	97		11,19		12,30
24 mois	3	99	4,80	86	5,35
	10		5,30		5,80
	50		7,15		7,35
	90		9,25		11,10
	97		10,00		11,85
36 mois	3	96	4,00	83	4,50
	10		4,45		5,20
	50		6,00		7,15
	90		7,95		9,35
	97		10,00		10,90

c) *Tissu cellulaire sous-cutané sous-scapulaire*

TABLEAU 4d

Percentiles d'épaisseur de tissu cellulaire sous-cutané

Age	Percentiles	Garçons		Filles	
		N	TCSC en mm	N	TCSC en mm
1 mois	3	108	2,95	95	3,04
	10		3,25		3,38
	50		4,34		4,72
	90		5,71		6,75
	97		6,35		8,83
3 mois	3	113	3,76	94	3,98
	10		4,49		5,44
	50		6,58		7,43
	90		9,94		9,97
	97		12,12		14,82
6 mois	3	114	5,14	100	5,07
	10		5,62		6,30
	50		8,30		8,40
	90		13,12		12,15
	97		16,92		17,00
9 mois	3	105	4,91	91	5,15
	10		5,30		6,21
	50		7,82		8,04
	90		11,45		13,18
	97		15,17		15,93
12 mois	3	105	4,12	90	4,54
	10		4,93		5,80
	50		7,53		8,36
	90		11,50		14,60
	97		13,59		17,33
18 mois	3	103	4,50	84	4,55
	10		5,00		5,44
	50		6,80		7,80
	90		11,00		14,92
	97		14,90		17,30
24 mois	3	99	3,80	86	4,50
	10		4,80		5,35
	50		6,80		7,90
	90		9,95		13,15
	97		14,85		17,35
36 mois	3	96	3,45	83	4,60
	10		4,25		5,25
	50		6,30		7,60
	90		9,80		10,35
	97		11,60		13,55

d) *Tissu cellulaire sous-cutané supra-iliaque*

TABLEAU 5a

Percentiles des accroissements d'épaisseur du tissu cellulaire sous-cutané

Périodes	Percentiles	Garçons		Filles	
		N	Accroissement de TCSC en mm	N	Accroissement de TCSC en mm
1 mois à 3 mois	10	95	- 0,37	82	- 0,36
	50		+ 1,45		+ 1,60
	90		+ 3,03		+ 3,68
3 mois à 6 mois	10	99	- 0,76	88	- 1,35
	50		+ 0,94		+ 1,03
	90		+ 2,74		+ 2,09
6 mois à 9 mois	10	89	- 0,84	79	- 0,87
	50		- 0,22		- 0,30
	90		+ 0,47		+ 0,47
9 mois à 12 mois	10	85	- 2,17	76	- 1,62
	50		- 0,58		- 0,40
	90		+ 0,98		+ 1,14
12 mois à 18 mois	10	92	- 2,00	75	- 2,05
	50		0,00		- 0,30
	90		+ 1,70		+ 1,70
18 mois à 24 mois	10	90	- 1,80	75	- 1,90
	50		- 2,00		- 0,18
	90		+ 1,50		+ 1,43
24 mois à 36 mois	10	87	- 1,60	77	- 2,10
	50		- 0,45		- 0,50
	90		+ 1,30		+ 0,80

a) *Tissu cellulaire sous-cutané du biceps*

Nous constatons donc que dans le cadre de notre travail la méthode longitudinale pure n'apporte pas de précision supplémentaire appréciable, tout en demandant un surcroît de besogne et en éliminant un certain nombre de sujets. Nous avons par conséquent pensé que pour les autres emplacements de tissu cellulaire sous-cutané nous pouvions sans inconvénients nous limiter à la seule méthode transversale.

Il est possible qu'une précision plus grande des paramètres pourrait être obtenue si l'on ne tenait compte que des sujets qui se sont présentés à tous les âges. Toutefois, ce procédé réduit l'échantillon à un point tel (environ 46 pour cent de l'effectif total) que la signification statistique des tests risque de s'en trouver compromise.

Les tableaux 4 a, b, c, d montrent l'évolution de l'épaisseur du tissu cellulaire sous-cutané chez les garçons et chez les filles de 1 mois à 3 ans.

L'épaisseur du tissu cellulaire sous-cutané sous-scapulaire est chez la fille, à tous les âges et à tous les percentiles, supérieure à celle des garçons. Le tissu graisseux mesuré aux autres endroits choisis est le plus souvent, mais pas toujours, plus épais chez la fille que chez le garçon.

Il existe une très large dispersion des valeurs normales : on enregistre à chaque âge des différences entre les

TABLEAU 5b

Percentiles des accroissements d'épaisseur du tissu cellulaire sous-cutané

Périodes	Percentiles	Garçons		Filles	
		N	Accroissement de TCSC en mm	N	Accroissement de TCSC en mm
1 mois à 3 mois	10	97	+ 0,54	85	+ 0,35
	50		+ 2,50		+ 2,14
	90		+ 4,18		+ 4,17
3 mois à 6 mois	10	100	– 1,45	88	– 1,44
	50		+ 1,57		+ 1,76
	90		+ 4,10		+ 5,02
6 mois à 9 mois	10	92	– 2,28	86	– 2,88
	50		+ 0,24		+ 0,05
	90		+ 2,96		+ 3,16
9 mois à 12 mois	10	86	– 2,28	79	– 2,82
	50		+ 0,29		+ 0,10
	90		+ 2,34		+ 2,31
12 mois à 18 mois	10	92	– 3,15	75	– 2,75
	50		– 0,15		+ 0,16
	90		+ 3,10		+ 3,90
18 mois à 24 mois	10	90	– 2,85	75	– 3,70
	50		– 0,20		– 0,00
	90		+ 3,60		+ 2,50
24 mois à 36 mois	10	87	– 3,95	77	– 4,20
	50		– 0,90		– 0,35
	90		+ 1,80		+ 2,10

b) *Tissu cellulaire sous-cutané du triceps*

percentiles 3 et 97, allant du simple au double. On peut en tirer une conclusion pratique pour le clinicien : pour juger du caractère normal du développement de l'épaisseur du tissu cellulaire sous-cutané, il faut se rapporter non pas à une simple table de moyennes, mais à des paramètres qui renseignent sur l'ampleur de la variation individuelle normale.

Les tableaux montrent dans l'ensemble une tendance à l'augmentation de l'épaisseur du tissu cellulaire sous-cutané de 1 à 6 mois, puis une stabilisation jusqu'à environ 12 mois, enfin une chute lente à partir de 12 mois.

En plus des valeurs absolues de percentiles de tissu cellulaire sous-cutané rapportées dans les tableaux 4, nous avons calculé les percentiles des valeurs des rapports de tissu graisseux à la taille. En inscrivant ces percentiles en ordonnée d'un graphique et l'âge en abscisse, on obtient des courbes assez parallèles qui permettent de constater que le bébé, déjà assez dodu à la naissance, l'est proportionnellement plus à six mois. Après six mois, les percentiles des rapports baissent régulièrement.

3. Distribution des accroissements d'épaisseur du tissu cellulaire sous-cutané

La méthode d'observation longitudinale de la croissance est la seule qui permette de déterminer de

TABLEAU 5c

Percentiles des accroissements d'épaisseur du tissu cellulaire sous-cutané

Périodes	Percentiles	Garçons		Filles	
		N	Accroissement de TCSC en mm	N	Accroissement de TCSC en mm
1 mois à 3 mois	10 50 90	94	- 0,56 + 1,10 + 2,98	78	- 0,52 + 1,43 + 4,26
3 mois à 6 mois	10 50 90	103	- 2,09 + 0,30 + 2,17	89	- 2,22 + 0,50 + 2,21
6 mois à 9 mois	10 50 90	90	- 1,75 - 0,20 + 2,30	84	- 1,76 + 0,09 + 1,73
9 mois à 12 mois	10 50 90	86	- 1,77 + 0,32 + 2,72	79	- 2,41 + 0,14 + 2,02
12 mois à 18 mois	10 50 90	92	- 2,65 - 0,65 + 1,50	74	- 2,32 - 0,40 + 2,72
18 mois à 24 mois	10 50 90	90	- 2,30 - 0,10 + 1,60	74	- 2,40 - 0,32 + 1,86
24 mois à 36 mois	10 50 90	87	- 3,15 - 0,80 + 0,70	77	- 2,85 - 0,60 + 1,60

c) *Tissu cellulaire sous-cutané sous-scapulaire*

manière valable les normes d'accroissement. Les percentiles des accroissements d'épaisseur de tissu cellulaire sous-cutané ont été calculés pour sept périodes successives : de 4 à 13 semaines, de 13 à 26, de 26 à 39, de 39 à 52 semaines, de 12 à 18 mois, de 18 à 24 et de 24 à 36 mois. Les tableaux 5 a, b, c, d donnent les percentiles des accroissements au cours des sept périodes envisagées. Il faut noter que les examens s'espacent de plus en plus au fur et à mesure que l'enfant grandit. L'inégalité des périodes pour lesquelles les accroissements ont été notés ne doit pas être oubliée si l'on utilise les tableaux 5 a, b, c, d à des fins de comparaison.

On constate une variation individuelle considérable dans la vitesse de l'accroissement. Ce dernier est régulièrement négatif au percentile 10 et toujours positif au percentile 90. Au percentile 50, l'accroissement est positif pendant le premier semestre de la vie ; pendant la deuxième partie de la première année, il devient très faible ou négatif. Nous n'avons pas inséré dans nos tableaux les percentiles 3 et 97 où les différences sont évidemment plus considérables encore. Il convient toutefois de rappeler que l'échantillon observé ne comprend que des enfants normaux ; par conséquent, les énormes variations rapportées doivent être considérées comme normales.

En plus des percentiles d'accroissement, nous avons

TABLEAU 5d

Percentiles des accroissements d'épaisseur du tissu cellulaire sous-cutané

Périodes	Percentiles	Garçons		Filles	
		N	Accroissement de TCSC en mm	N	Accroissement de TCSC en mm
1 mois à 3 mois	10 50 90	97	+ 0,37 + 2,02 + 5,02	85	+ 0,43 + 2,67 + 6,08
3 mois à 6 mois	10 50 90	102	- 1,18 + 1,63 + 4,92	89	- 1,44 + 1,23 + 4,51
6 mois à 9 mois	10 50 90	95	- 4,50 - 0,83 + 2,57	86	- 3,90 - 0,28 + 3,86
9 mois à 12 mois	10 50 90	86	- 4,83 - 0,60 + 2,54	77	- 3,32 + 0,30 + 3,75
12 mois à 18 mois	10 50 90	92	- 3,60 - 0,45 + 2,80	74	- 4,96 - 0,95 + 3,92
18 mois à 24 mois	10 50 90	90	- 2,90 - 0,35 + 2,50	74	- 5,66 - 0,27 + 5,32
24 mois à 36 mois	10 50 90	87	- 3,15 - 0,35 + 2,40	77	- 4,35 - 0,30 + 2,60

d) *Tissu cellulaire sous-cutané supra-iliaque*

aussi calculé les moyennes d'accroissement pour les sept périodes envisagées. Elles sont indiquées aux tableaux 6 a, b, c, d.

Dans l'ensemble, aucune différence statistiquement significative ne peut être mise en évidence entre les accroissements d'épaisseur de graisse chez les garçons et chez les filles.

On n'enregistre des moyennes d'accroissement régulièrement positives aux quatre niveaux envisagés (biceps, triceps, sous-scapulaire, supra-iliaque) que pendant les deux premières périodes de temps considérées. De 6 à 12 mois, il semble que l'on assiste à une redistribution du tissu cellulaire sous-cutané: les enfants, tant garçons que filles, tendent à gagner de la graisse en certains endroits du corps (région postérieure: triceps et sous-scapulaire) et à en perdre en d'autres (région antérieure: biceps et supra-iliaque). A partir de 18 mois, l'enfant, manifestement, s'amincit, il y a diminution générale de l'épaisseur du tissu cellulaire sous-cutané.

TABLEAU 6a

Accroissements d'épaisseur de tissu cellulaire sous-cutané

Périodes en mois	Garçons			Filles		
	Nombre de cas	Moyenne en mm	Ecart-type en mm	Nombre de cas	Moyenne en mm	Ecart-type en mm
de 1 à 3 m.	99	1,38	0,13	87	1,55	0,16
de 3 à 6 m.	104	0,98	0,13	92	0,65	0,15
de 6 à 9 m.	97	- 0,31	0,12	88	- 0,48	0,12
de 9 à 12 m.	90	- 0,43	0,12	80	- 0,23	0,12
de 12 à 18 m.	92	0,05	0,15	75	- 0,16	0,14
de 18 à 24 m.	90	0,27	0,14	75	- 0,15	0,12
de 24 à 36 m.	87	- 0,21	0,14	77	- 0,50	0,11

a) *Tissu cellulaire sous-cutané du biceps*

TABLEAU 6b

Périodes en mois	Garçons			Filles		
	Nombre de cas	Moyenne en mm	Ecart-type en mm	Nombre de cas	Moyenne en mm	Ecart-type en mm
de 1 à 3 m.	99	2,50	0,17	87	2,31	0,17
de 3 à 6 m.	104	1,62	0,23	92	1,91	0,23
de 6 à 9 m.	97	0,34	0,21	88	0,11	0,24
de 9 à 12 m.	90	0,18	0,20	80	- 0,35	0,22
de 12 à 18 m.	92	- 0,17	0,24	75	+ 0,78	0,31
de 18 à 24 m.	90	- 0,02	0,24	75	- 0,25	0,23
de 24 à 36 m.	87	- 0,91	0,22	77	- 0,71	0,23

b) *Tissu cellulaire sous-cutané du triceps*

TABLEAU 6c

Périodes en mois	Garçons			Filles		
	Nombre de cas	Moyenne en mm	Ecart-type en mm	Nombre de cas	Moyenne en mm	Ecart-type en mm
de 1 à 3 m.	99	1,35	0,18	87	1,48	0,19
de 3 à 6 m.	104	0,10	0,19	92	0,24	0,19
de 6 à 9 m.	95	0,16	0,17	88	0,12	0,15
de 9 à 12 m.	88	0,57	0,17	80	0,14	0,18
de 12 à 18 m.	92	- 0,58	0,17	74	- 0,22	0,20
de 18 à 24 m.	80	- 0,18	0,16	75	- 0,25	0,19
de 24 à 36 m.	87	- 0,92	0,17	77	- 0,60	0,18

c) *Tissu cellulaire sous-cutané sous-scapulaire*

TABLEAU 6d

Périodes en mois	Garçons			Filles		
	Nombre de cas	Moyenne en mm	Ecart-type en mm	Nombre de cas	Moyenne en mm	Ecart-type en mm
de 1 à 3 m.	99	2,50	0,22	87	2,82	0,24
de 3 à 6 m.	104	1,95	0,28	92	1,41	0,30
de 6 à 9 m.	97	- 0,79	0,32	88	- 0,28	0,34
de 9 à 12 m.	90	- 0,71	0,27	80	0,21	0,35
de 12 à 18 m.	92	- 0,37	0,29	74	- 0,42	0,35
de 18 à 24 m.	90	- 0,27	0,34	75	- 0,03	0,45
de 24 à 36 m.	87	- 0,55	0,27	77	- 0,77	0,35

d) *Tissu cellulaire sous-cutané supra-iliaque*

RÉSUMÉ

L'article décrit des observations relatives à l'évolution du tissu cellulaire sous-cutané pendant les trois premières années de vie, chez un groupe d'enfants suivis longitudinalement.

Il présente pour les divers âges étudiés les moyennes, les écarts-types et la distribution par percentiles. De plus, les variations de l'épaisseur du tissu graisseux au cours des périodes d'âge envisagées sont exprimées sous forme de percentiles et de moyennes.

L'auteur commente les résultats obtenus que l'on peut résumer de la façon suivante:

1) Le pannicule adipeux des filles est plus abondant que celui des garçons.

2) L'épaisseur absolue du tissu cellulaire sous-cutané diminue dès l'âge d'un an.

3) Il existe, chez des enfants considérés comme normaux, une énorme dispersion des vitesses d'accroissement du tissu cellulaire sous-cutané.

SUMMARY

The article describes observations relating to the evolution of fat-thickness during the first three years of life among a group of longitudinally observed children.

The author states for the different ages the means, standard-errors and percentiles. Moreover, the changes of fat-thickness are expressed in the form of percentiles and means.

The author comments the results which may be summed up in the following way:

1) The girls are fatter than the boys.

2) The absolute fat-thickness decreases from the age of one.

3) There is a large range in the increment of fat-thickness among children who are considered as quite normal.

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Etude longitudinale du développement intellectuel de la naissance à dix-huit ans *

Par F. de Borggraef-Rauis, C. Emery-Hauzeur; E. A. Sand

Depuis vingt ans se poursuit dans plusieurs centres européens et notamment à Bruxelles, une étude longitudinale coordonnée de la croissance et du développement de l'enfant normal. Les descriptions détaillées de ces études ont été exposées précédemment. (Graffar, 1959; Sand, 1959; Falkner, 1960.)

L'étude longitudinale menée à Bruxelles portait, à l'origine, sur un groupe de 263 enfants belges, nés à terme, représentatif au plan socio-économique de la population des années 1955-1958 de Saint-Gilles, faubourg de Bruxelles. Depuis leur naissance, ces enfants sont examinés régulièrement au Centre, tant au point de vue somatique qu'au point de vue psychologique. Des enquêtes sociales menées au domicile des familles complètent ces renseignements. Supposer qu'un groupe de personnes reste identique à lui-même pendant vingt ans reviendrait à en nier la dynamique. Au cours des années, des abandons se sont succédé, au rythme moyen de 5 % par année. A l'âge de 18 ans, l'échantillon était de 120 enfants. (Graffar et Meyfroet, 1970.)

Les mesures et renseignements d'ordre somatique et psychologique ont été recueillis pour tous les enfants aux intervalles suivants: tous les trois mois durant les deux premières années de la vie, ensuite tous les ans à une date proche de leur anniversaire et enfin, de trois en trois ans dès l'âge de 15 ans.

En ce qui concerne le volet social de l'étude, six enquêtes ont été effectuées depuis le début de l'étude.

L'étude du développement psychologique de l'enfant comporte, entre autres données, une évaluation du développement intellectuel effectuée à l'aide de tests appropriés. Nous nous proposons d'exposer certains aspects du développement intellectuel, tel que nous avons pu l'observer dans cet échantillon et les diverses influences temporaires ou persistantes qu'il subit. Nous comparerons certains de nos résultats à d'autres issus de recherches transversales ou longitudinales.

MÉTHODOLOGIE

Dès l'âge de trois mois, les enfants ont été soumis à des épreuves psychomotrices et, ultérieurement, à des tests intellectuels. Le test de Brunet-Lézine (1954) a été inclus dans l'examen psychologique à trois, six, neuf, douze, dix-huit et vingt-quatre mois. Il englobe dans son évaluation le développement moteur, la coordination, la réaction sociale et le langage. A partir de trois ans, nous avons fait appel au test de Terman-Merril (Adaptation française, F. Cesselin, 1959) qui a été appliqué aux enfants tous les deux ans jusqu'à l'âge de onze ans. Ce test a l'avantage, par l'utilisation d'épreuves présentant d'âge en âge certaines similitudes, de pouvoir être répété au cours du temps et s'est ainsi particulièrement bien inséré dans une optique longitudinale. A quatorze ans, un test intellectuel évaluant les différentes «aptitudes mentales primaires» de l'intelligence, le P.M.A. 11-17 ans de Thurstone, a succédé au Terman. Enfin, à dix-huit ans, un test d'intelligence générale non verbale, le D 70, et une épreuve de compréhension verbale de G. Meuris ont constitué la batterie intellectuelle.

RÉSULTATS

Voici dans un premier temps, l'étude descriptive des résultats obtenus aux épreuves de développement et aux tests intellectuels, à chaque niveau d'âge.

Dans un deuxième temps, nous dresserons un tableau des corrélations inter-âge et nous nous intéresserons plus particulièrement aux corrélations entre les résultats obtenus pour les différents facteurs du P.M.A. à 14 ans et les quotients intellectuels évalués aux autres niveaux d'âge.

Enfin, dans une troisième étape, nous étudierons les corrélations entre les scores aux tests et diverses variables sociales, biologiques et familiales.

Signalons qu'un éventuel effet «examinateur» a été analysé avant d'entreprendre cette étude (De Borggraef-Rauis et Sand, 1971). En effet, les épreuves intellectuelles ont été appliquées par plusieurs examinateurs et on pouvait se demander si les différences, parfois importantes, observées dans les résultats n'étaient pas dues à des différences dans la façon de présenter l'épreuve ou d'apprécier la qualité de la réponse donnée. Une analyse de variance n'a pas permis de rejeter l'hypothèse nulle, l'effet «examinateur» n'a donc pas été pris en considération.

1. Distribution des scores aux tests d'intelligence

Rappelons que la distribution théorique des quotients intellectuels est de forme gaussienne avec une moyenne égale à 100 et un écart-type de 15 points. (INED et INOP, 1969.) Les distributions issues des observations de la présente étude sont proches de ces normes théoriques avec toutefois une dispersion variant selon l'âge du groupe d'enfants observés. Notons que

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Terman (1937) obtient des distributions de Q.I. dont l'écart-type moyen est de 16.4, les valeurs extrêmes observées sont respectivement de 14 et 18 points de Q.I. Cesselin (1959), lors de l'adaptation française du Terman, observe un écart-type moyen de 14.6.

Les résultats que nous avons observés dans l'étude longitudinale sont les suivants: dans le tableau 1, sont reportés les moyennes et écarts-types obtenus à chaque niveau d'âge. (Nous avons inclus dans ce tableau, pour le lecteur que la comparaison intéresse, les résultats de l'étude transversale de Cesselin.) La figure 1 montre graphiquement l'évolution des notes bruxelloises.

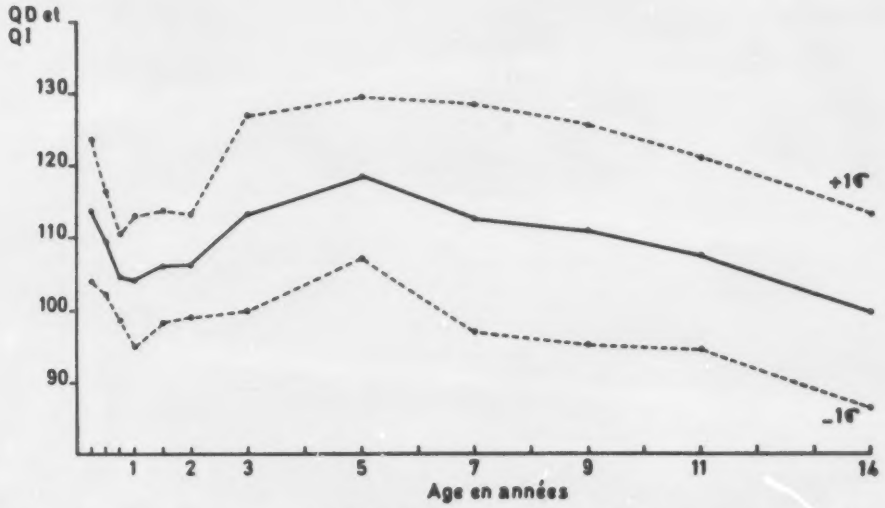

Fig. 1 Courbes des moyennes et de la dispersion des QD et QI de la naissance à 14 ans.

Nous remarquons que jusqu'à l'âge de deux ans, les résultats sont groupés autour d'une moyenne générale de 107, et on observe une diminution lente de la moyenne des résultats à chaque âge. A partir de trois ans, la moyenne générale des résultats aux tests intellectuels s'élève de 5 points. Exprimée graphiquement, la moyenne des résultats dès l'âge de trois ans suit une courbe ascendante qui trouve son point culminant à cinq ans et redescend progressivement pour atteindre à quatorze ans une valeur égale à 100. Quant à la dispersion des résultats, peu importante pendant la petite enfance, elle s'étale dès l'âge de trois ans et atteint un niveau où elle se stabilisera jusqu'à l'adolescence.

Cette évolution en sinusoïde du développement mental et la faible dispersion des résultats durant la petite enfance appellent quelques commentaires.

Dans l'ensemble, la moyenne des résultats se situe à un niveau supérieur à 100. Le groupe d'enfants étudiés, tout en étant représentatif de la population de cette commune, est essentiellement un échantillon urbain. Terman remarquait déjà en 1937 que les moyennes des Q.I. établis sur des groupes d'origine urbaine, étaient supérieures de 10 points à celles des groupes d'origine rurale.

A l'âge de cinq ans, nous observons que les résultats aux tests sont en majorité supérieurs à ceux obtenus les années précédentes et suivantes. Ce pic peut être expliqué par la fréquentation scolaire-maternelle, importante à cet âge. Goodenough (1940) a montré que le Q.I. d'un groupe peut s'élever de 5 à 7 points lorsque les enfants fréquentent un enseignement pré-scolaire et ceci à tous les niveaux de l'échelle sociale. Lorsque Terman et Merril ont fait la révision et l'adaptation du test de Binet en 1937, la fréquentation des classes maternelles était loin d'être aussi généralisée qu'elle ne l'est actuellement.

En ce qui concerne la dispersion des résultats, nous voyons que dans la petite enfance, le groupe d'enfants étudiés est assez homogène, les notes s'écartent peu de la moyenne. Ce n'est qu'à partir de trois ans que la répartition des notes prend de l'ampleur; des résultats aux tests, très faibles et très élevés apparaissent; la distribution des notes, peu dispersée jusqu'alors, s'étale et garde jusqu'à dix-huit ans, âge du dernier testing, une dispersion proche des normes théoriques.

En d'autres termes, lorsque le développement mental s'écarte de la coordination psycho-motrice pour s'engager vers trois ans, dans l'organisation des opérations concrètes de classes de nombres de relations, on constate que les notes se différencient et que la dispersion des résultats devient plus large. Nous verrons plus loin que ceci n'est pas le seul changement qui apparaisse à partir de cet âge.

TABLEAU 1

Moyennes et dispersion des résultats aux tests de développement et intellectuels aux divers âges.
Données du Centre de la Croissance de Bruxelles et données de Cesselin.

Age	Tests	Bruxelles		Cesselin	
		Moyenne	Ecart-type	Moyenne	Ecart-type
		Q.D.			
3 mois	Brunet-Lézine	113.7	9.7		
6 mois	Brunet-Lézine	109.4	7.2		
9 mois	Brunet-Lézine	104.4	5.9		
12 mois	Brunet-Lézine	104.1	9.1		
18 mois	Brunet-Lézine	106.	7.8		
24 mois	Brunet-Lézine	106.2	7.2		
		Q.I.			
3 ans	Terman	113.3	13.5		
5 ans	Terman	118.3	11.3		
6 ans	Terman		104.3	14	
7 ans	Terman	112.7	15.9	103.1	15.4
8 ans	Terman		101.3	17.2	
9 ans	Terman	111.	15.8	103.7	16.6
10 ans	Terman		99.4	16.4	
11 ans	Terman	107.7	13.2	98.2	14.6
14 ans	PMA	99.9	13.5		
		Notes			
18 ans	D 70	27.8	6.8		
18 ans	Meuris	26.	9.6		

II. Corrélations inter-âge et inter-test.

1. Valeur prédictive du Q.D. et du Q.I.

Nous avons calculé les corrélations entre les notes obtenues aux tests aux divers âges, pour étudier la valeur prédictive d'un résultat à un âge donné par rapport à un autre âge. Il importait de déterminer si le groupe restait homogène et semblable à lui-même du point de vue intellectuel.

Le tableau des corrélations (tableau 2) indique que l'importance de la corrélation est fonction de l'âge des enfants et de l'intervalle de temps entre deux tests. La prédiction est bonne pour de courtes périodes (r = .50 entre 9 et 12 mois), les résultats obtenus pendant la petite enfance ne permettent pas de formuler un avis sur les scores futurs des enfants (r = .29 entre deux ans et quatorze ans). Cependant au-delà de l'âge de cinq ans, les corrélations restent à un niveau de signification élevé, même si elles décroissent quand l'intervalle de temps augmente ($P < .001$). Les performances intellectuelles des enfants observés semblent donc présenter une plus grande stabilité dès l'âge de cinq ans. Toutefois, il faut remarquer que si il y a de fortes chances pour que les enfants ayant des notes élevées à cinq ans, aient en majorité des scores élevés à dix-huit ans, il existe néanmoins une variabilité individuelle dans les résultats aux tests appliqués aux différents âges (Bayley, 1949; Sontag, Baker et Nelson, 1958; De Borggraef et Sand, 1971).

Nos résultats s'accordent avec les conclusions d'autres études concernant la stabilité des résultats aux tests intellectuels. Ainsi, N. Bayley (1949) estime que les scores obtenus aux tests d'intelligence avant l'âge de dix-

huit mois ont une valeur prédictive très pauvre et qu'une stabilité croissante se marque entre cinq et six ans et est suivie d'une longue période de stabilité après cet âge pour la plupart des enfants. Pour Kagan et Moss (1959), avant l'âge de deux ans, l'intelligence et le niveau éducationnel des parents sont de meilleurs prédicteurs de l'intelligence de l'enfant lorsqu'il aura dix ans que les propres scores de l'enfant.

TABLEAU 2

Corrélations entre les notes obtenues aux Tests aux divers âges.

			Brunet-Lézine					Terman (forme M)					PMA	Meuris	D 70
N	Tests	Age	6M	9M	12M	18M	24M	3A	5A	7A	9A	11A	14A	18A	18A
189	Brunet-Lézine	3M	.34	.38	.38	.26	.27	.19	.12	.24	.19	.16	.15	.01	.02
193		6M	.55	.50	.43	.29	.34	.22	.28	.21	.34	.20		.14	.15
186		9M		.56	.45	.41	.35	.24	.34	.26	.29	.23		.28	.20
190		12M			.55	.51	.37	.27	.33	.30	.23	.26		.10	.21
190		18M				.61	.48	.34	.36	.20	.31	.25		.18	.21
190		24M					.54	.43	.41	.32	.41	.29		.21	.29
178	Terman Forme M	3A						.63	.64	.58	.59	.27		.42	.27
155		5A							.72	.65	.67	.45		.52	.37
131		7A								.74	.71	.53		.65	.55
115		9A									.82	.56		.72	.49
113		11A										.59		.78	.52
103	PMA	14A												.57	.70
103	Meuris	18A												.55	
111	D 70	18A													

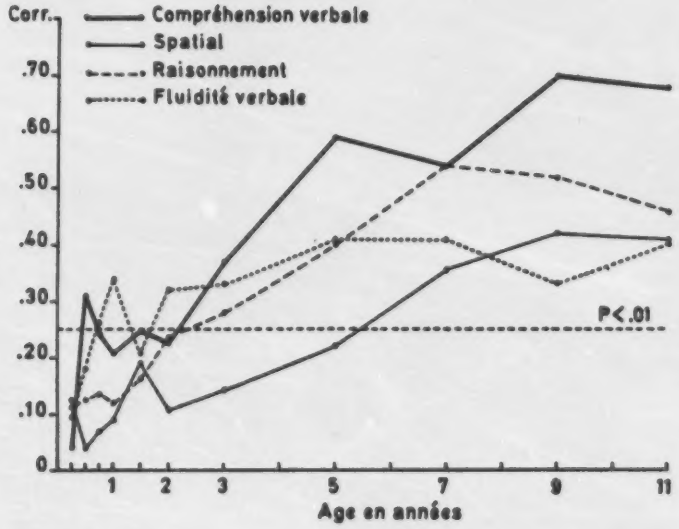

Fig. 2 Corrélations entre les résultats au P.M.A. à 14 ans et les scores intellectuels et de développement à d'autres niveaux d'âge.

2. PMA et développement intellectuel.

Le test des aptitudes mentales primaires de Thurstone (1) a été utilisé à quatorze ans. Il a été appliqué dans son entièreté, mais nous n'avons retenu que quatre des cinq aptitudes: verbal, spatial, raisonnement, et fluidité verbale. Nous avons été amenés à ne pas tenir compte du facteur numérique pour les raisons suivantes: alors que la moyenne des résultats pour les autres facteurs se situe en général en classe 6, la moyenne des résultats au facteur numérique se trouve en classe 3. Cette baisse particulière des notes au facteur numérique relève sans doute du changement dans l'enseignement de la mathématique.

L'exercice spécifique de rapidité dans le maniement des chiffres, qui est mesuré par le facteur numérique, n'intervient plus dans l'enseignement de la mathématique moderne. Bien souvent les enfants l'évoquaient spontanément après la passation du test par des phrases de ce type: «On n'y est plus habitué».

Quatre des aptitudes primaires du test de Thurstone ont été corrélées aux notes intellectuelles établies aux autres âges. Les corrélations sont reportées graphiquement dans la figure 2.

Avant l'âge de trois ans, les corrélations sont fluctuantes et restent pour la plupart en dessous du niveau de signification de .01. Toutefois, les aptitudes verbales paraissent plus précocement corrélées aux scores obtenus aux autres épreuves (six mois pour la signification verbale, neuf mois pour la fluidité verbale). Au-delà de trois ans, les corrélations deviennent plus stables et augmentent régulièrement en fonction de l'âge.

(1) Batterie Factorielle du P.M.A. (Aptitudes Mentales Primaires) 11-17 ans. Centre de Psychologie Appliquée, Square Jouvenel, Paris XVI^{e}.

Il nous paraît intéressant de relever certaines observations dans l'évolution des corrélations entre les aptitudes mentales primaires testées à quatorze ans et les résultats globaux de QD et QI antérieurs. Ces corrélations acquièrent une valeur significative au seuil de .01 à un âge où dans le développement intellectuel ces fonctions apparaissent. Ainsi l'aptitude au raisonnement, qui est une épreuve de classes, d'ensembles, maintient une corrélation au-delà d'un niveau de signification à .01 à partir de l'âge de trois ans, période où au point de vue intellectuel se préparent et s'organisent les opérations concrètes de classes, relations et nombres. De même l'aptitude spatiale, aptitude à imaginer comment un objet apparaîtra lorsqu'il aura subi une rotation, se corrèle de façon significative ($P < .01$) avec les notes intellectuelles à partir de sept ans. C'est également à ce niveau d'âge, dans le développement intellectuel que la pensée de l'enfant devient réversible, qu'elle se détache de la perception immédiate et devient ainsi opérationnelle.

III. Corrélations entre les notes aux tests et des variables biologiques, sociales et familiales.

Nous avons étudié l'existence éventuelle d'associations entre des variables biologiques et d'environnement et le développement intellectuel, de même que le sens de ces associations et le moment où elles interviennent. Ces variables sont les suivantes:

1. Sexe de l'enfant.
2. Rang de l'enfant dans la famille.
3. Age de la mère à la naissance de l'enfant.
4. Dimension de la famille.
5. Classe sociale.
6. Niveaux d'instruction des parents.

Nous étudierons les corrélations éventuelles de ces variables d'abord au niveau des cotes globales (QD et QI) ensuite au niveau des aptitudes mentales primaires.

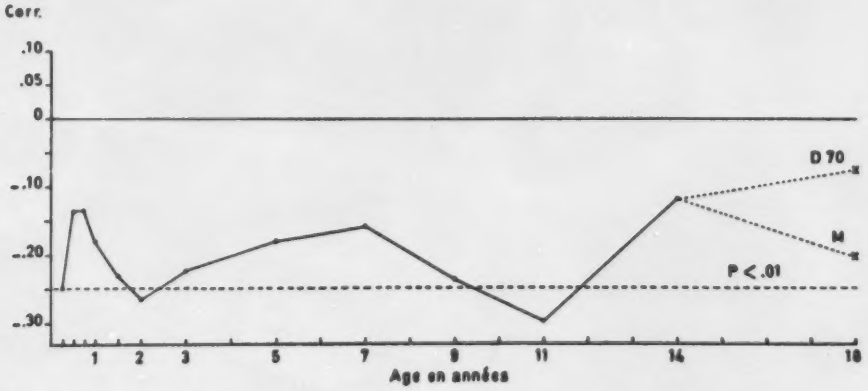

Fig. 3 Corrélations entre le rang de l'enfant dans la fratrie et ses résultats aux tests de développement et intellectuels de 3 mois à 18 ans.

A. QD et QI et variables biologiques et d'environnement:

1. Le sexe de l'enfant; l'âge de la mère.

Qu'il s'agisse d'une fille ou d'un garçon, que la mère soit jeune ou âgée à la naissance de l'enfant, aucune de ces variables ne semble influencer les quotients de développement et les quotients intellectuels et cela quel que soit l'âge de l'enfant.

2. Le rang de l'enfant dans la fratrie.

On observe à certains âges une tendance à une association négative mais de peu de poids entre la place occupée par l'enfant au sein de la fratrie et son développement intellectuel. On verra plus loin que cette association est sans doute l'expression d'une autre association qui existe entre la dimension de la fratrie et le rang occupé par l'enfant dans cette fratrie.

3. La dimension de la famille.

La dimension de la famille est celle qui a été notée au douzième anniversaire de l'enfant, les familles ayant alors toutes atteint leur dimension définitive.

De nombreuses diverses études concernant l'existence d'une relation entre la dimension de la famille et le niveau intellectuel des enfants qui la composent ont été entreprises. Il s'agit en majorité d'études transversales, à caractère national, s'appliquant à des enfants en âge de scolarité obligatoire (6-11 ans) et de ce fait couvrant la quasi totalité de la population infantile de la région étudiée (Migliorino, 1971-1972; Maxwell, 1961; Vital and Health Statistics, 1974).

Deux conclusions se dégagent de ces études: en premier lieu la dimension de la famille est très souvent associée au niveau socio-économique: les familles les plus nombreuses appartiennent aux classes les plus défavorisées. La seconde conclusion est que le niveau intellectuel des enfants et leur maturité intellectuelle (Vital and Health Statistics, 1974) diminuent progressivement au fur et à mesure qu'augmentent les dimensions de la famille.

En ce qui concerne l'Etude de la Croissance de Bruxelles, la dimension des familles fréquentant le Centre varie de 1 à 8 enfants, la moyenne est de 2,6 enfants par famille et l'écart-type de 1.54.

Nous n'avons pas dans notre échantillon beaucoup de familles fort nombreuses: huit d'entre elles ont six enfants et plus, et aucune ne compte plus de huit enfants.

Bien que l'échantillon soit, au point de vue socio-économique, représentatif de la population urbaine bruxelloise, il n'existe pas de liens entre la dimension de la famille et le niveau socio-économique qui est le sien ($r = .16$).

L'étude d'un rapport éventuel entre la dimension de la famille et le QI de l'enfant a été basée sur les coefficients de corrélation. Ils ont été calculés pour chaque niveau d'âge depuis trois mois jusqu'à dix-huit ans. (Fig. 4.)

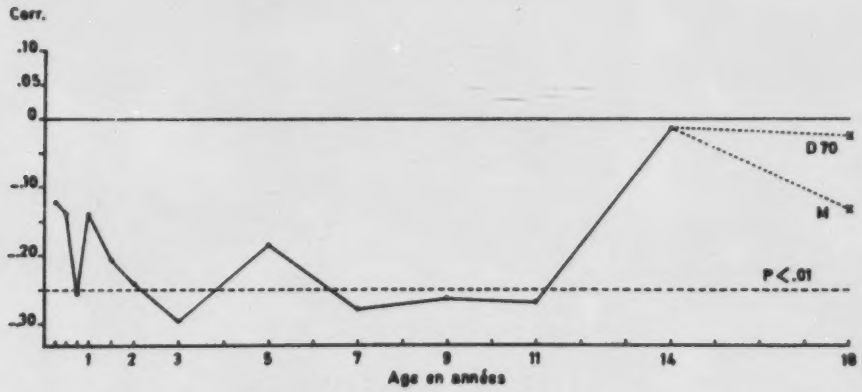

Fig. 4 Corrélations entre la dimension de la famille et les scores de développement et intellectuels de l'enfant de 3 mois à 18 ans.

Nous constatons que la corrélation entre la dimension de la famille et le quotient de développement intellectuel de l'enfant est négative, d'importance croissante au fur et à mesure que l'enfant avance en âge et que cette corrélation garde un niveau de signification élevé ($P < .01$) jusqu'à l'âge de onze ans. Au-delà de cet âge, la corrélation disparaît.

En d'autres termes, principalement pendant la période de scolarité primaire, les enfants de familles nombreuses ont en moyenne un QI inférieur à celui des enfants de familles peu nombreuses. Ceci rejoint les observations émanant des études transversales citées plus haut, pour la période d'âge considérée. Mais il importe de souligner qu'au-delà de l'âge de onze ans,

cette différence dans les résultats aux tests intellectuels en fonction de la dimension de la famille disparaît.

Il semble que le phénomène observé sur le plan longitudinal peut trouver une explication au niveau de la croissance intellectuelle. Piaget (1955) définit les stades qui nous intéressent de la façon suivante : « L'étape qui s'étend de 7-8 ans à 11-12 ans est la sous-période des opérations concrètes. Elle est caractérisée par une série de structures en voie d'achèvement. Enfin, vient la troisième et dernière période, celle des opérations formelles, dès 11-12 ans, avec un palier d'équilibre vers 13-14 ans. »

Tout semble se passer comme si chaque période de croissance intellectuelle était parcourue à un rythme différent selon les enfants, les uns ayant une maturation d'une nouvelle structure intellectuelle plus rapide que d'autres. Le QI établi pendant une période de développement intellectuel donnée mesure aussi la rapidité de ce développement. Lorsque l'ensemble du groupe a atteint la maturité d'une fonction intellectuelle donnée, celle-ci s'intègre aux structures précédentes et il se crée un palier d'équilibre. A ce stade, chaque enfant a atteint son propre plafond. Le QI établi à ce moment est alors dégagé de l'effet « vitesse de développement » et est une mesure plus exacte du potentiel intellectuel de chacun des enfants. La dimension de la famille en soi ne semble donc jouer aucun rôle au niveau des capacités intellectuelles de l'individu : le fait d'avoir de nombreux frères et sœurs ou d'être enfant unique ne rend pas plus ou moins intelligent. Mais on peut supposer que la dimension de la famille influence le rythme individuel dans l'approche de la maturité d'une fonction intellectuelle particulière.

4. Classes sociales et niveaux d'instruction des parents.

La classe sociale a été déterminée par le système de classification de Graffar (1956). Cinq critères sont utilisés par cet auteur : le niveau d'instruction des parents, la profession, la source de revenus, le type de logement, le quartier (lieu d'habitation). La somme des cotes attribuées à chacun de ces critères donne lieu à une cote de niveau social global correspondant à cinq « classes ». Notons que pour le calcul des corrélations nous avons tenu compte de la cote globale, variable continue, de préférence à l'appartenance à l'un des cinq niveaux. La classe sociale prise en considération ici est celle déterminée lors de la deuxième enquête sociale effectuée lorsque les enfants avaient entre un et deux ans d'âge. On n'a pas tenu compte de l'enquête faite à la naissance, ceci dans le dessein de saisir le contexte social de la famille suffisamment précocement, mais dans une situation plus stabilisée (emploi plus stable, service militaire ou études achevés, changement vers un logement plus adapté...).

Les niveaux d'instruction des parents, qui font partie des critères de classification sociale, nous ont paru particulièrement importants pour cette étude. Ils apportent une information précise concernant le degré éducationnel et culturel de la famille. C'est pourquoi nous les avons étudiés séparément bien qu'ils interviennent dans la classe sociale globale.

Voici comment se répartit l'échantillon selon les cinq niveaux socio-économiques, la classe 1 étant le niveau le plus élevé, la classe 5, le niveau le plus bas.

TABLEAU 3

Répartition de l'échantillon bruxellois selon le critère classe sociale

	Classes sociales					
	1	2	3	4	5	Total
N	4	36	92	53	9	194
%	2	19	47	27	5	100

De nombreuses études ont monté que le quotient intellectuel moyen d'un groupe d'enfants varie en fonction du niveau socio-économique des parents. (Loevinger, 1940, Scottish Council for Research in Education, 1953, Anastasi, 1958, Sand, Emery et coll., 1975).

Des études longitudinales européennes (Sand, 1966, Hindley, 1967) ont montré que les quotients intellectuels et de développement évoluent différemment selon la classe sociale des parents.

Il est sans doute intéressant de rappeler que cette relation n'existe pas pendant les premières années de la vie. L'étude longitudinale menée à Berkeley (Californie) par M. Honzik et ses collaborateurs a pu mettre en évidence, à partir de trois, quatre ans, une corrélation entre le statut socio-économique des parents et les résultats aux tests d'intelligence de l'enfant. Avant cet âge, la corrélation était nulle ou négative (Bayley et Jones, 1937). Autre phénomène intéressant qui apparaît dans l'étude de Berkeley : les corrélations entre les niveaux d'instruction des parents et les notes obtenues aux tests intellectuels par leur enfant, quasi nulles jusqu'à l'âge de deux ans, deviennent significatives à partir de trois-quatre ans. (Bayley, 1954.)

Le même phénomène s'observe dans l'étude longitudinale de Bruxelles (fig. 5 et 6). Les corrélations entre le quotient intellectuel de l'enfant et le milieu social dans lequel il grandit ne sont pas significatives jusqu'au début de la troisième année. A partir de cet âge, les corrélations deviennent rapidement significatives ($P < .01$) et maintiennent ce niveau de signification jusqu'à 18 ans, âge des derniers tests. Les corrélations entre le développement intellectuel de l'enfant et le niveau d'instruction des parents suivent pratiquement la même évolution : une corrélation significative à .01 apparaît à partir de la troisième année.

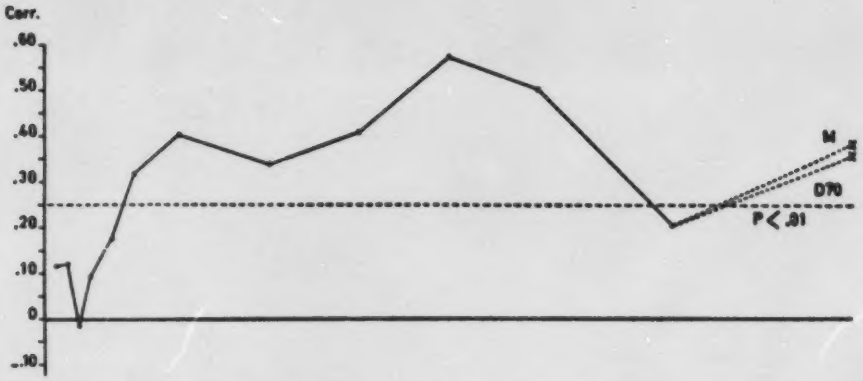

Fig. 5 Corrélations entre la classe sociale et les scores de développement et intellectuels de l'enfant de 3 mois à 18 ans.

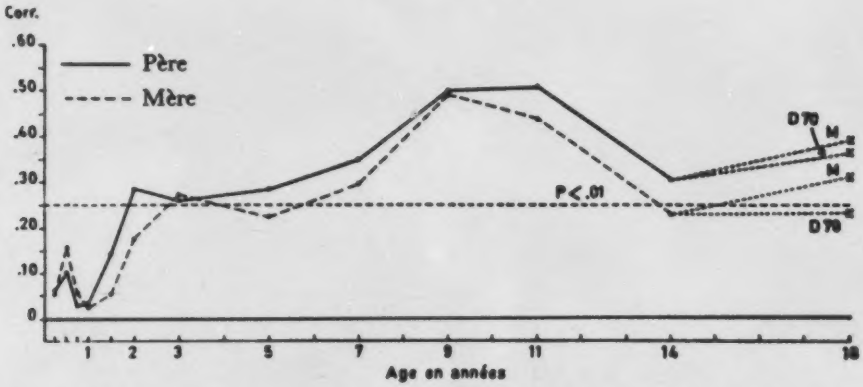

Fig. 6 Corrélations entre les niveaux d'instruction des parents et les scores de développement et intellectuels de l'enfant de 3 mois à 18 ans.

B. Aptitudes mentales primaires évaluées à 14 ans et variables biologiques et d'environnement.

1. Variables familiales.

Que la mère soit jeune ou âgée à la naissance de l'enfant, que la fratrie soit nombreuse ou non, que l'enfant soit aîné ou cadet, toutes ces variables n'influencent en rien les potentialités d'une fonction mentale particulière.

2. Le sexe de l'enfant.

Nous avons déjà pu constater, en ce qui concerne le Q.I., que le fait d'être garçon ou fille n'apportait aucune différence dans les résultats.

Au niveau des aptitudes primaires, évaluées à l'aide du P.M.A., deux des quatre facteurs envisagés ont un développement plus important selon qu'il s'agit d'un garçon ou d'une fille. L'habileté à manier des formes dans l'espace est davantage l'apanage des garçons ($X^2 = 14.6$; $P < .001$) et la fluidité verbale celui des filles ($X^2 = 6.3$; $P < .05$).

3. Classe sociale et niveaux d'instruction des parents.

En ce qui concerne l'association entre le niveau socio-économique de la famille, le degré d'instruction des parents et les Aptitudes Mentales Primaires, nous constatons que deux d'entre elles sont spécifiquement influencées par ces variables. Il s'agit de la connaissance verbale et du raisonnement. Très nettement, l'aptitude à la connaissance des mots et de leur signification et l'aptitude au raisonnement sur des données logiques sont d'autant plus développées, en moyenne,

que la famille est d'un niveau socio-économique élevé ou que les parents ont atteint respectivement des degrés d'instruction élevés. (Fig. 7.)

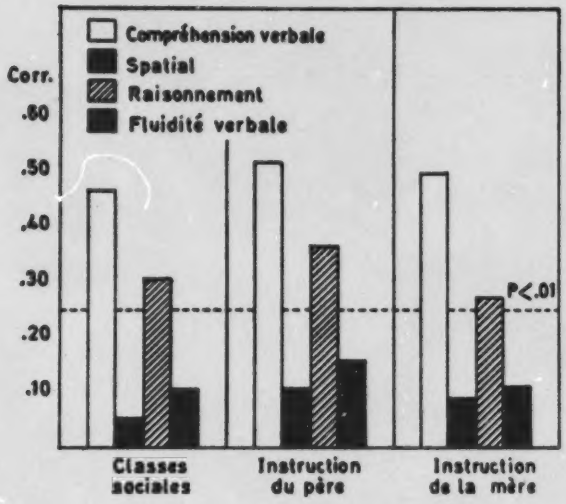

Fig. 7 Corrélations entre les résultats au P.M.A. à 14 ans et des variables sociales et d'instruction parentale.

Le facteur spatial, dont nous avons déjà vu que la corrélation avec le quotient intellectuel n'apparaissait que tardivement, n'est lié ni à l'appartenance à une classe sociale quelconque, ni à l'instruction des parents. De même la fluidité verbale, l'aisance dans l'expression verbale, reste une aptitude indépendante de tout contexte socio-économique.

CONCLUSIONS ET RÉFLEXIONS

Il ressort de ces résultats que la troisième année de la vie constitue une période importante dans l'évolution de l'intelligence : les résultats aux tests se dispersent, les niveaux socio-culturels et les Q.I. s'associent positivement. A cette période d'âge, nous l'avons déjà souligné, apparaissent une série de fonctions et de structures nouvelles qui se développent en chaîne jusqu'à onze-douze ans. Et, sans période préparatoire, dès que débutent ces opérations de classes, de nombres, de relations, une association apparaît entre le niveau socio-culturel des parents et le développement intellectuel des enfants. Cette association est-elle la conséquence de l'influence de l'environnement au cours de cette période, ou est-elle l'expression de différences individuelles préexistantes qui apparaissent au fur et à mesure que les différents stades dans le développement intellectuel sont atteints ?

Que l'intelligence soit le résultat de l'action combinée des variables d'environnement et du potentiel génétique est évident et bien connu.

Dans la part qui revient à chacun des constituants, les travaux des généticiens peuvent apporter plus de précisions. Il serait fort long de faire ici une revue des études et travaux génétiques portant sur l'intelligence. Nous ne citerons que deux travaux qui nous paraissent parmi les plus importants.

Les travaux de Skodak et Skeels (1949) portant sur l'influence de l'environnement sur le développement intellectuel, ont montré que les enfants adoptés obtenaient un QI supérieur en moyenne de 20 points, à celui de leurs parents naturels, mais gardaient néanmoins un niveau intellectuel beaucoup plus proche de celui de parents naturels que de celui de leurs parents adoptifs.

Beaucoup plus récemment, Jensen (1970) étudie 122 paires de jumeaux séparés dans les premiers mois de la vie et élevés dans des milieux différents. Il démontre que le QI (phénotype) est égal à la somme du génotype et de l'effet environnement, qu'il y a somme et non interaction et que 85 % de la variance du Q.I. relève de l'hérédité.

Nous n'avons pu étudier, dans notre échantillon, l'aspect génétique de l'intelligence, mais aux vues de ces découvertes, il nous semble important d'en garder la notion dans l'interprétation des résultats.

On peut donc estimer que chaque groupe social est caractérisé par un certain bagage génétique. Certaines aptitudes intellectuelles ont acquis, socialement, une importance plus grande que d'autres. Une faiblesse innée dans les aptitudes intellectuelles peut être compensée par un effet «environnement optimal». Un effort pédagogique précoce, visant à créer cet environnement optimal et s'adressant aux enfants qui cumulent un bagage génétique faible et un environnement pauvre, est évidemment à souhaiter. (Heber et Garber, comm. pers.)

En conclusion de cette étude longitudinale du développement intellectuel, nous pouvons dire :

1. Les notes aux tests, peu dispersées et homogènes durant les deux premières années de la vie, se différencient et la dispersion des résultats augmente dès l'âge de trois ans.

2. La moyenne des quotients intellectuels de notre échantillon se situe au-dessus de la moyenne théorique de 100. Ceci peut être attribué au caractère urbain de notre échantillon.

3. La dimension de la famille freine la vitesse de maturation des fonctions intellectuelles, mais ne semble pas influencer les capacités intellectuelles futures.

Le quotient intellectuel n'est associé au niveau socio-culturel de la famille qu'après l'âge de deux ans. Cette relation est le résultat d'un double effet, environnement et génétique.

Des aptitudes mentales primaires, nous retiendrons qu'elles sont corrélées positivement avec le quotient intellectuel à un âge qui est particulier à chaque aptitude. Le niveau de la connaissance verbale et du raisonnement sont meilleurs, en moyenne, chez les enfants issus de familles à niveau socio-culturel élevé. Enfin, indépendant de tout contexte socio-culturel, le facteur spatial est, en général, plus développé chez les garçons, la fluidité verbale mieux développée chez la fille.

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Croissance et maturation de l'enfant à Dakar *

Par Geneviève Massé, Professeur à l'Ecole nationale de la Santé publique de Rennes (France)

Un centre d'étude du développement de l'enfant a été fondé à Dakar, en 1954, par le Centre international de l'enfance, sous la direction du Professeur Jean Sénécal. Il devait opérer en coordination avec les autres centres créés par cet organisme; c'est-à-dire mener, selon des bases communes, une recherche longitudinale concernant un même groupe d'enfants, tout au long de leur développement.

Les conditions à Dakar étaient évidemment très différentes de celles dans lesquelles étaient placés les groupes d'étude européens ou américains, qu'il s'agisse du patrimoine génétique des enfants ou du milieu dans lequel ils se développaient.

Pour être efficace, l'étude longitudinale, qui permettrait de décrire le dynamisme de la croissance et de la maturation, devait pouvoir se référer à des standards indiquant les niveaux atteints, à Dakar, par les enfants «normaux». Or ces standards n'existaient pas; et il a fallu les créer au moyen d'enquêtes transversales, c'est-à-dire en mesurant une seule fois, à un moment donné, des enfants d'âges différents.

STANDARDS DE CROISSANCE ET DE MATURATION DANS LES PAYS EN DÉVELOPPEMENT

Il était urgent d'établir de tels standards, dans l'intérêt de la recherche certes, mais également pour procurer des critères valables aux pédiatres et au personnel de santé publique chargé de surveiller la santé des enfants. Il est évident que ces critères sont particulièrement importants dans les pays où les enfants sont intensément exposés aux risques cumulés de la malnutrition, des infections répétées, du parasitisme massif, facteurs inhibiteurs du développement.

Pour établir ces standards, quels enfants doit-on mesurer? On pourrait sélectionner les enfants élevés dans les milieux particulièrement favorisés, dont les conditions de vie sont comparables à celles des milieux aisés des pays industrialisés. Les normes déterminées de cette façon représenteraient le développement optimum que l'on peut attendre, dans l'état actuel de nos connaissances, pour les types génétiques considérés.

Cette manière de faire présente deux inconvénients: tout d'abord, l'effectif restreint des enfants se trouvant dans ces conditions est soumis à de fortes fluctuations aléatoires. Ensuite, lorsque l'on se référera aux normes ainsi établies lors de l'examen des enfants tout-venants, on risque d'estimer comme au-dessous des «limites de la normale», des enfants dont l'état de santé n'atteint pas les standards des pays de niveau élevé, mais peut être considéré satisfaisant dans les conditions présentes.

A Dakar, les enfants observés étaient privilégiés en ce sens qu'ils appartenaient le plus souvent à des milieux non indigents et relativement stables, et que tous étaient astreints à une surveillance médicale régulière. Mais parmi eux se trouvaient des enfants présentant de légers signes d'avitaminoses; chez les nourrissons, on remarquait des signes discrets de malnutrition protidique; certains accusaient des poussées fébriles paludéennes; beaucoup hébergeaient des parasites intestinaux. N'ont été éliminés que les sujets chez qui les manifestations parasitaires ou carentielles étaient marquées.

A la nécessité de mesurer des enfants dont on sait l'état de santé satisfaisant, s'ajoute un autre contrainte: leur âge doit être connu avec certitude. Il s'agira donc d'enfants possédant un acte de naissance, ou d'enfants suivis par un service depuis leur naissance.

GROUPES ÉTUDIÉS À DAKAR ET SES ENVIRONS

1. Enquêtes transversales

Jusqu'à 18 mois, les enfants sont suivis dans les dispensaires de la presqu'île du Cap-Vert (où se trouve Dakar) (1952-1954).

De deux à sept ans, des enfants suivis par le service médical de la caisse d'allocations familiales (1956-1957).

A l'âge scolaire: 1° Tous les enfants des écoles (années 1953-1954) possédant un acte de naissance. A l'époque le taux de scolarisation était de 36 % (28 % pour les filles, 51 % pour les garçons). La scolarisation était plus forte dans les milieux aisés, commerçants et fonctionnaires (53 %). Parmi les enfants scolarisés, environ la moitié possédait un acte de naissance; ces enfants pour la plupart étaient nés dans une ville, ou à proximité.

2° Certains écoliers des années 1954-1955 et 1956-1957. Ajoutons qu'à la même époque, une analyse des *poids des naissances* fut réalisée à la Maternité de Dakar (où avaient lieu 48 % des naissances de cette ville).

2. Enquête longitudinale

356 enfants nés à la Maternité de Dakar entre avril 1954 et mars 1956 furent suivis jusqu'à 7 ans. Après une interruption de quelques années, l'étude de leur développement fut reprise en 1967 (Pr Satgé, Dr Bouthreuil, Dr Niang), et continuée sur les mêmes enfants. Ces enfants pesaient au moins 2500 grammes à la naissance; ils étaient exempts de malformations congénitales. Leurs familles percevaient des salaires ou des revenus réguliers; les pères étaient essentiellement des ouvriers (21 %), des employés (51 %), des artisans (17 %), des petits commerçants (7 %).

* Nous remercions les «Carnets de l'Enfance» de nous avoir permis de reproduire ce travail paru dans les «Carnets de l'Enfance» 1971, 15: 36-45.

CARACTÈRES COUTUMIERS

Ils ont été observés lors de l'étude longitudinale. Très rapidement résumés, ceux qui sont susceptibles d'influer le développpement se présentent ainsi :

Tous les enfants ont été nourris au sein ; l'allaitement maternel, pratiqué « à la demande » s'est prolongé en moyenne jusqu'à 18 mois ; pour la majorité des enfants, aucun autre aliment ne l'a complété avant 9 mois. Vers cet âge ont été données des bouillies sucrées (mil, fruit du baobab), riches en hydrates de carbone ; rarement un peu de lait caillé ; la ration était donc pauvre en protéines, déséquilibrée en faveur des hydrates de carbone. Aucun de ces enfants n'a été atteint de kwashiorkor, mais 16 % d'entre eux ont présenté des signes de malnutrition protidique fruste entre 9 et 24 mois. Peu à peu, l'enfant a appris à glaner sa nourriture dans le plat familial commun, mais c'est vers 2 ans et demi seulement que tous les enfants ont pu satisfaire pleinement leurs besoins nutritionnels en participant réellement à l'alimentation familiale, qui semblait adéquate.

Pendant les premiers mois, l'enfant vit en étroite symbiose avec sa mère, ne quittant pas le contact de son corps et participant à toutes les activités sociales de celle-ci. Ces liens se relâchent au fur et à mesure que l'enfant acquiert une certaine autonomie locomotrice ; puis plus rapidement au moment du sevrage ; mais nous n'avons pas observé à ce moment précis la séparation brutale décrite dans d'autres régions d'Afrique noire. Vers cet âge commence à se manifester une certaine carence éducative du milieu familial urbain : absence de jouets, absence d'apprentissage pré-scolaire, par exemple.

RÉSULTATS

Ils se sont traduits, jusqu'à présent, par quelque 80 tableaux de chiffres, et autant de graphiques, et nous ne pouvons en donner qu'un rapide aperçu. Pour fixer les idées, nous les comparons ici aux résultats concernant les enfants européens et américains blancs. Nous indiquons s'il s'agit des résultats de l'enquête longitudinale ou des enquêtes transversales.

De la naissance au 4e mois (étude longitudinale)

La croissance pondéro-staturale et la maturation osseuse ont tendance à être plus rapides que chez l'enfant européen ou américain blanc.

La comparaison avec l'échantillon parisien montre une différence de 1,9 cm et 510 g en faveur des garçons dakarois, et de 1,4 cm en faveur des filles dakaroises, celles-ci accusant cependant un poids moyen inférieur de 160 g.

Le grand os et l'os crochu apparaissent environ 1 mois et demi plus précocement à Dakar qu'à Boston.

Quant aux niveaux de développement psychomoteur, à 4 semaines, ceux des enfants qui ont été observés (par le Dr Faladé) se comportaient comme des enfants européens de 12 semaines (test de Gesell) ; à 16 semaines, les niveaux européens correspondants allaient de 19 semaines pour l'adaptivité à plus de 24 semaines pour la locomotion.

Entre 3 mois et 2 ans (étude longitudinale)

On note un ralentissement relatif :

— de la croissance pondéro-staturale, après le 3e mois ;
— de la maturation osseuse, après le 9e mois ;
— du développement psycho-moteur, après le 12e mois.

Ce phénomène est à mettre en parallèle avec le déséquilibre alimentaire mentionné plus haut ; mais les conditions d'observation n'ont pas permis de prouver une relation de cause à effet.

Le *ralentissement pondéro-statural* aboutit, par comparaison avec Paris, à des poids inférieurs à partir de 3 mois, même chez les garçons ; à des tailles qui, après avoir été supérieures de 3 à 9 mois dans les deux sexes, sont inférieures ensuite. A 2 ans, le déficit est de 7 % pour le poids, et de 3 % pour la taille.

La maturation osseuse est plus précoce en moyenne jusqu'à 18 mois. Puis on note, à 2 ans, un retard moyen de 2 à 9 mois selon les centres osseux.

De 6 mois à 1 an, l'avance moyenne du *développement psycho-moteur*, est de 2 mois (test de Brunet-Lézine) ; à 18 mois, les enfants ont rejoint les Européens puis une stagnation des acquisitions s'installe de 18 mois à 2 ans.

De 2 ans à la puberté (étude longitudinale jusqu'à 7 ans transversale ensuite).

Le poids reste inférieur à celui des enfants français ; mais la moyenne, qui se situe à — un écart-type des normes françaises à 2 ans et demi, se hausse ensuite et se maintient à — un demi écart-type, au maximum, jusque vers 11 ans et demi.

La taille redevient égale à celle des Français à 4 ans pour les garçons, et 5 ans pour les filles ; cette égalité se maintient jusqu'à 9 ans et demi chez les garçons, 10 ans et demi chez les filles.

La maturation osseuse accuse un « retard » constant, de 10 mois environ.

La maturation psycho-motrice a été mesurée jusqu'à 6 ans (étude longitudinale) ; à 3 ans, le quotient intellectuel, mesuré par le test de Termann-Merrill, était redevenu à peu près égal à celui des enfants français. A 4 ans, la moyenne avait légèrement baissé. De 4 à 6 ans, les enfants n'ont semblé faire aucune acquisition. Il se peut que la première phase de ralentissement soit en rapport avec le déséquilibre alimentaire (mais les conditions d'observation ne permettent pas de le prouver) et le sevrage. La deuxième phase, après 3 ans, semble due à la carence éducative (absence d'école maternelle et de matériel éducatif). Depuis l'époque de nos observations, les pédagogues ont souvent souligné que le manque d'acquisitions des enfants africains pendant la période pré-scolaire rend très difficile l'adaptation à l'école.

L'ENFANT RURAL

Dans une étude faite en milieu rural (Khombole), Debroise et ses collaborateurs (1967) trouvent des poids et des tailles bien inférieurs aux nôtres, même chez des

enfants «suivis de façon assez régulière... par des visites systématiques effectuées dans les villages mêmes...»

La taille médiane des filles rurales se maintient de 3 mois à 6 ans entre les 3e et 10e centiles des filles de Dakar; celle des *garçons* est inférieure au 3e centile à celle des garçons dakarois à 3, 6, 12 mois, 3 ans, 4 ans, 5 ans, et se hausse entre le 3e et le 10e centiles à 18 et 24 mois, et de nouveau à 6 ans.

Le poids médian des filles rurales se situe entre le 10e et le 20e centile des filles dakaroises à 3 mois, au 10e centile à 6 mois, entre le 3e et le 10e à 12 mois, aux environs du 10e à 18 mois jusqu'à 3 ans inclus; puis rejoint le 20e centile à 4 ans, le le 30e à 5 ans, et se trouve entre le 20e et le 30e à 6 ans.

Celui des *garçons ruraux* se maintient entre le 3e et le 10e centile des garçons de Dakar de 3 mois à 3 ans inclus, il grimpe au 20e centile à 4 ans, au 30e à 5 ans, au 40e à 6 ans.

Il faut remarquer qu'il ne s'agit pas d'une «étude longitudinale pure», c'est-à-dire que les mesures à un âge donné concernent les survivants de cet âge.

Les poids et tailles d'enfants ruraux, qui n'ont subi aucune action médicale ou nutritionnelle, sont encore plus faibles que ceux-ci.

LES VARIATIONS SAISONNIÈRES

On sait que la croissance subit des variations saisonnières, d'autant plus nettement que les conditions de vie sont moins bonnes.

A Dakar, et encore plus en milieu rural, la croissance est moins rapide pendant la saison humide. Il semble qu'agissent à la fois des facteurs climatiques, et — surtout en milieu rural — nutritionnels.

CONCLUSION

Les termes de comparaison qui ont été utilisés ici: «avance», «retard», «déficit» sont évidemment ambigus; ils semblent impliquer un jugement de valeur, que le seul examen des courbes de croissance et de maturation ne permet pas de porter, en l'absence d'autres critères.

En ce qui concerne le nourrisson, la rapidité de développement des premières semaines s'accompagne d'un aspect général très satisfaisant; l'enfant est particulièrement gai, épanoui, actif. Par contre, le ralentissement observé par la suite correspond à une phase où l'enfant est grognon, d'aspect malheureux — même s'il ne présente pas de signes spécifiques de malnutrition.

La signification de la baisse du quotient intellectuel observée après 3 ans tient à ce que cette diminution est liée à une déficience de l'apprentissage pré-scolaire, apprentissage nécessaire pour une bonne adaptation ultérieure à un enseignement de type scolaire.

En l'absence de tests d'aptitude à l'effort physique et intellectuel et de mesure de morbidité, on ne peut savoir si le léger «déficit» pondéral enregistré chez l'écolier est défavorable.

A la puberté, si le «retard» de la maturation sexuelle est en harmonie avec le «retard» de la maturation osseuse et le «retard» staturo-pondéral, le résultat final sera satisfaisant. C'est ce que nous montrera la recherche en cours.

SUMMARY

A longitudinal research-project (bearing on a same group of children right through the period of their development) has been under way in Dakar since 1954. These children belonged to relatively stable and non-indigent families. Furthermore, they were subjected to regular medical supervision.

This study does not claim therefore to reflect the situation of all children living in the Dakar area. Standards of reference were determined by transversal surveys carried out on different groups.

These children have a certain number of characteristics in common:

1. They are breast-fed until the age of 18 months and suckled when they demand it; but after the age of 6 months their food ration appears unbalanced.
2. During the first months the child lives in symbiosis with its mother, in permanent bodily contact with her. These links loosen only gradually, and there is not the brutal separation at the weaning period which is to be found in other regions of black Africa.

The results of these observations indicate that:

1. From birth to the fourth month, increase of weight and height and maturation of the bone structure tend to be more rapid in the African child than in the European or white American one; same observation for the levels of psycho-motor development.
2. On the other hand, between three months and two years a relative slowing down of the increase in weight and height (as of the third month), of bone maturation (after the ninth month) and of psycho-motor development (after the twelfth month) are to be noted.
3. From two years to the age of puberty, the weight remains lower than that of French children, the height becomes equal to that of a French child (as of four years for boys and as of five years for girls); bone maturation shows an unvarying backwardness of some ten months; psycho-motor maturation is roughly equal to that of the French child at the age of 3, but seems to make no progress between four and six years.

Comparison with a study undertaken in rural surroundings shows that the children of this milieu have a height and weight inferior to those of the town children. Their growth and development are subject to seasonal variations, all the more obvious since the living conditions are less good. Finally, growth is less rapid during the wet season.

Thus, if the baby is born and develops in generally favourable surroundings, the slowing down which has been observed as of the weaning period would seem to indicate the existence of nutritional—and above all educational—deficiencies as regards the child. This deficiency in pre-school training reveals itself to be a big handicap in good adaptation to normal school education.

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Skeletal Maturation of the Hand and Wrist in West African Children *

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INTRODUCTION

The major existing qualitative methods of assessing skeletal maturation of the hand and wrist were originally developed on children growing up under unusually favorable circumstances of health and nutrition. The aim of the present paper is to test the adequacy of these procedures when applied to children maturing under adverse conditions. It is based on a sample of West African children resident in Dakar, Sénégal. The methods of assessment are qualitative ratings of the shape of x-ray images of the bones, without consideration of size.

Two of the most important current qualitative procedures are the "atlas" method of Greulich and Pyle (1959), and the "maturity score" or Oxford method (Acheson, 1954, 1957; Tanner, 1962). Two steps were necessary for the design of both procedures: (1) the formulation of a sequence of standards, and (2) the transformation of these standards into a scale of measurement.

Greulich and Pyle (1950, 1959) classified the roentgenograms of a homogeneous group of American children from northern Ohio according to age and sex. Inside each age-sex category, the films were ranked according to maturity. The single film chosen as representative of this category was modal with respect to as many details of skeletal maturation as possible.

The Oxford method does not characterize films by age and sex. For each ossific center, the roentgenograms are distributed from the least to the most mature, without consideration of age. A series of standards is then chosen arbitrarily out of the developmental continuum so that each standard represents a clearly definable shape of the center, common to all children, and recognizable at sight by a trained observer.

Both the atlas and the Oxford method end up with a sequence of standards from the least to the most mature. The transformation of these standards to a scale of measurement differs, however.

Greulich and Pyle (1959) produce a time scale for each sex and center of ossification, expressed in years and months. For a particular child, his "bone age" at the time when a particular film is taken is the mode of the separate ratings of the local osseous sites within the film. This chronology of bone ages can be regarded as an interval scale if age is counted from birth, or as a ratio scale if the origin is at conception.

In the Oxford method, the number assigned to each osseous center is its rank in the sequence of all standards of this center alone. The numbers 1, 2, 3, 4, etc., represent the successive stages of a center from onset to maturity. This sequence therefore represents an ordinal scale.

Two problems arise in adapting the Greulich-Pyle and Oxford methods to the present population of African children: whether the succession of shapes of particular bones is the same, and whether the interrelations of stages in the different centers are so peculiar that a global "skeletal age" or even the Oxford score of an African child is only approximately comparable with such an overall index of development of an American or European child.

Even in healthy White children, such a global numerical index of development is somewhat misleading because different regions of the carpal and phalangeal skeleton show only moderate interrelationships with one another.

Robinow (1942) applied a factor analysis to a selection of osseous centers in the limbs. He found two rather distinct groups of developing centers in the hand and wrist: one consisting of carpal bones, and the other comprising the epiphyses of the long bones and the sesamoids. Within each group, all centers tend to be relatively advanced or retarded, but this pattern is virtually independent of the advancement or retardation of the other group.

Some of the earlier workers suspected that they had elucidated effects of acute illness on the ossification of the hand. Todd (1937), and later Francis and Werle (1939) concluded that such episodes produced delayed development of the carpal bones more often than decelerated maturation of the epiphysial centers.

These conclusion were not confirmed by later workers, at least on prosperous American children. As shown especially by work at the Fels Institute, the chief mechanism of aberrant timing of carpal ossification is probably hereditary, and seems not to be modifiable by the frequency of illness (Sontag and Lipford, 1943; Garn and Rohmann, 1960).

According to Dreizen *et al.* (1954), chronic malnutrition retards all of the 28 centers which they observed in the hand, but not to the same extent. The most generally retarded centers are the middle and distal phalangeal epiphyses. The capitate and hamate are the least retarded.

Jones and Dean (1956) have described the effects of kwashiorkor on the maturation of the hand. They found that the epiphyses of the middle phalanges are the most retarded.

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In all of these cases, studies of exogenous and hereditary influences of the maturation of particular bones have helped to define different groups of centers with characteristic regional chronologies of development.

Another useful approach, to be used in the present study, is to examine the variability of attainment of developmental stages in each center in samples of children of the appropriate ages. This variability is an indication of the sensitivity of the center to the many factors which may act on its onset and rate of ossification. Where different variabilities characterize different centers, it is likely that their sensitivities to these factors are correspondingly unlike.

MATERIAL AND METHODS

In the present study a sample of African children was investigated, ranging in age from 10 days to 15 years, and all resident in Dakar. About 70 % were from the Ouolof ethnic group, about 15 % were Toucouleurs, and the rest mainly Bambaras and Sérérés. These ethnic affiliations were ascertained by interrogation of the child or his mother, and by checking his name.

The data on infants consisted of observations on 100 boys and 100 girls who were enrolled in a longitudinal growth study. The youngest films were taken at no more than three days away from 10 days, and no more than a week away from the following ages: 3, 6, 9, 12 and 18 months.

A different sample of children from two to six years of age were examined within a week of their birthdays. These subjects were being followed by the Family Allocation Service. This agency of the government provides cash for the parents only if they bring their children in regularly for medical checkups.

A third sample aged seven to 15 years consisted of students in the schools, and were also examined within a week of their birthdays.

From two to 12 years of age, 100 boys and 100 girls of each age group were studied. At 13 to 15 years, the numbers of each sex varied from 45 to 95.

This method of recruitment has a number of effects on the data. From 10 days to 18 months, the observations for the different ages are not independent. Furthermore, it was necessary to test the continuity of the three groups: the longitudinal sample of infants, the pre-school, and the school samples.

This test consisted of comparisons of the radiographic data at three years of age in the longitudinal sample with the statistics at the same ahe on the pre-school corss-section sample. These comparisons yielded no significant differences between the two groups.

A similar test was not possible between the pre-school and school children, since their ages did not overlap. Nevertheless, these two samples had markedly similar origins. Both were born in or near an urban center at known dates, since their births had been registered. They belonged to a stable, not a destitute, part of the population, and underwent medical visits at least once a year. Beyond these similarities, however, some intangible differences between the samples may not have been evident to us.

In order to find the distribution of ages at which our Dakar children arrived at stages of skeletal development, four successive stages of maturation were defined for each skeletal center of the hand and wrist, except that five stages were used for the distal epiphyses of the radius and ulna, and only one stage for the pisiform and the adductor sesamoid of the first metacarpal.

These stages were chosen from among the "maturity indicators" of Greulich and Pyle (1950), but only the most easily recognizable stages were retained. The standards of the first edition were used because at the time the second edition, with somewhat altered pictorial standards, had not yet been published (Greulich and Pyle, 1959). This simplification was inspired by the papers of Acheson (1954, 1957), on the Oxford method, which appeared at the time of our investigation.

The location of the pictorial definitions of all the stages are presented in tables 1-3, so that the reader can refer back to Greulich and Pyle (1950) for precise identifications of all of them. Despite the small number of stages employed here, a total of 116 resulted for the entire hand and wrist, for each sex. Here we present in detail only the data for the girls.

At the appropriate ages, the percentages of children at or beyond each stage were transformed into an attainment line, a procedure used by several workers, and discussed in Hunt, Cocke and Gallagher (1958).

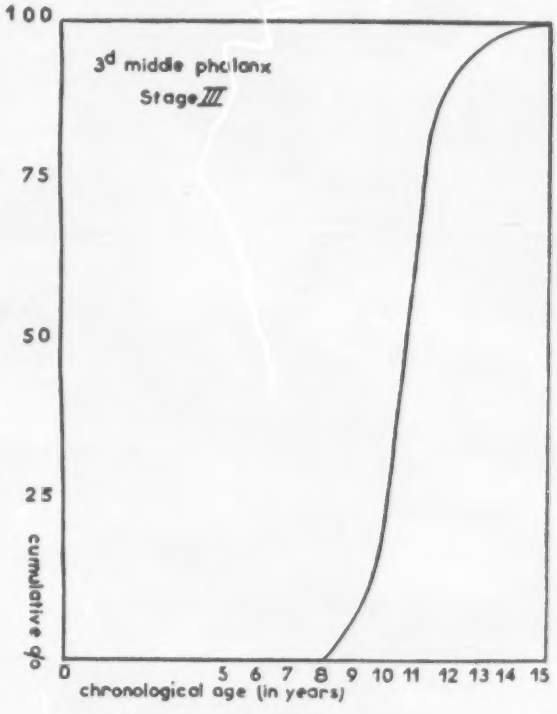

Fig. 1A. Original Attainment Curve.

An attainment line is a cumulative percentage distribution plotted on age. Where age is transformed into the logarithm of age from the estimated time of conception, a normal ogive is generally produced. The abscissa is then the age axis.

The transformation of the normal ogive to a straight line is accomplished by transforming the ordinate percentages to standard deviation units, or the equivalent normalized t-scores or probits.

The ordinate transformed in this manner has an origin at the 50th percentile. The value + 1 standard deviation corresponds to percentile 84.13, and the percentile 15.87 represents —1 on the scale of standard deviation units.

Under these conditions, the slope of the cumulative frequency line (attainment line) is the reciprocal of the distance along the abscissa from the 50th to the 84.13th percentile. The standard deviation in log units of such a distribution has useful properties. Where two attainment lines are parallel on a graph, they have identical slopes, or identical distributions or percentiles, but different mean ages. Identity of slope, furthermore, can be taken as evidence of physiologic responses of different developing organs to similar trophic stimuli.

Some other authors have used attainment lines in studies of sexual maturation (Hunt, Cocke and Gallagher, 1958), and dental eruption (Kihlberg and Koski, 1954). When a single organ system is studied, and a succession of stages defined for its development, a family of attainment lines can be found for these stages, and a number of cases of marked parallelism have been revealed, particularly in the teeth (Fanning, 1960).

In general, then, the present study is an attempt to classify groups of parallel attainment lines by age and by clusters of osseous centers. A brief discussion follows on the existence of this system as seen in a longitudinal sample of Boston children (Harding, 1952), as well as in a sample of Dakar children with kwashiorkor. These comparative studies are described in greater detail elsewhere (Massé, 1960).

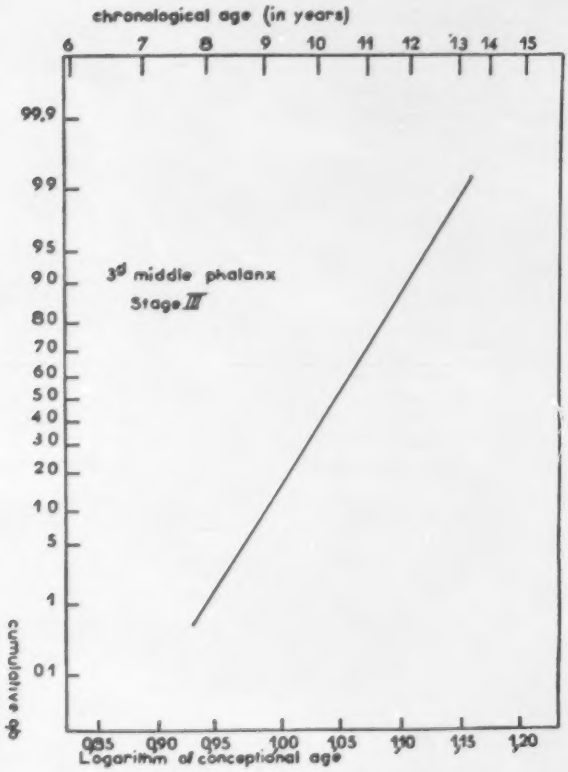

Fig. 1B. Transformation of Skewed Attainment Curve. Age Transformed to Eliminate Skewness. Percentile Axis Transformed to Produce Linear Attainment Curve.

FINDINGS

Tanner (1962, p. 61) states that "There is an invariable order in which the successive steps of development occur in each bone." In the Dakar population, this generalization applies with two anomalous exceptions. In 1.1 % of the girls from 10 to 15 years of age, the triquetrum and lunate become fused. This phenomenon was also seen in 1.3 % of the boys from 12 to 15 years of age. This pattern, which affects only two bones, is too infrequent to complicate the use or racially White standards on the present West African sample.

In the examination of attainment lines, parallelism of slopes was not found to occur throughout the age span studies. Instead, three cycles of nearly parallel lines were revealed: each specific to part of the time span of development of the hand. The first cycle extends from 10 days to 5 years of age. The boundary is not so clear-cut between the second and third cycles, but occurs at about 10 years of age, as shown in tables 2 and 4.

For the purpose of this study, these lines were fitted to the data by eye. In a diversity of attainment lines this procedure agrees with leastsquares fits to within about ± 0.003 log units. Since the class-intervals in tables 4 and 5 are spaced 0.03 log age units apart, the evidence presented here is practically identical to what would have been found by more precise mathematical methods.

The median ages on the graphs and tables are accurate to the nearest ½ month to 18 months, to the nearest month up to 30 months, to the nearest three months up to six years, nd to the nearest six months later than six years.

When the distribution of percentages in the three age-periods were compared by means of the chi-square test, they were very significantly different from one another ($p < 0.001$).

Although the three phases of osseous development seem clear in this population, one might question whether the difference between the longitudinal infant sample and the pre-school cross-sectional sample might

partly result from differences in the methods of recruitment. One might expect, for example, that the longitudinal sample might show restricted variability of attainment of osseous stages. Such a possibility, however, was not found.

Within each phase, we then looked for groupings of bones with still more exact parallelism, and attempted to see whether such lesser groupings in some cases extended from any earlier chronological cycle into a later one.

TABLE 1

Medians and reciprocals of slopes of attainment lines of developmental stages of the hand, Dakar and Boston girls, birth to 4 years old

Osseous center	Stage (Greulich-Pyle 1950)	Dakar girls		Boston girls	
		Median age of onset in months	Reciprocal of slope in log units	Median age of onset in months	Reciprocal of slope in log units
Capitate	I	0.7	.07	2.0	.08
Hamate	I	1.0	.09	2.5	.09
Capitate	III	6.0	.08	—	—
3rd proximal phalanx	I	7.5	.10	9.5	.06
4th proximal phalanx	I	8.0	.11	10.0	.06
1st distal phalanx	I	8.0	.16	11.0	.08
Hamate	IV	8.5	.14	—	—
Radius	I	8.5	.15	10.0	.10
2nd proximal phalanx	I	8.5	.10	10.0	.06
2nd metacarpal	I	9.5	.10	12.0	.08
3rd metacarpal	I	9.5	.10	13.5	.07
4th middle phalanx	I	10.5	.14	13.5	.09
3rd middle phalanx	I	10.5	.13	14.0	.08
4th metacarpal	I	11.0	.10	15.0	.07
5th proximal phalanx	I	13.0	.08	10.0	.05
5th metacarpal	I	13.0	.10	16.0	.07
Radius	III	13.5	.14	—	—
2nd middle phalanx	I	13.5	.20	15.0	.13
4th distal phalanx	I	13.5	.18	17.0	.08
3rd distal phalanx	I	14.0	.18	16.5	.08
5th middle phalanx	I	18.0	.19	21.5	.11
1st proximal phalanx	I	19.0	.13	19.0	.08
2nd proximal phalanx	V	23.0	.10	—	—
3rd proximal phalanx	V	23.0	.07	—	—
4th proximal phalanx	V	23.0	.09	—	—
2nd distal phalanx	I	23.0	.13	22.5	.06
1st metacarpal	I	24.0	.12	15.0	.06
2nd metacarpal	IV	24.0	.12	—	—
5th proximal phalanx	V	24.0	.10	—	—
5th distal phalanx	I	25.0	.18	22.0	.08
Triquetrum	I	30.0	.20	24.0	.12
3rd metacarpal	IV	30.0	.11	—	—
1st distal phalanx	III	30.0	.20	—	—
Radius	IV	36.0	.15	—	—
4th metacarpal	V	36.0	.11	—	—
Triquetrum	III	42.0	.18	—	—
Hamate	VII	48.0	.11	—	—
Lunate	I	48.0	.12	30.0	.14
5th metacarpal	V	48.0	.12	—	—
2nd middle phalanx	IV	48.0	.19	—	—

TABLE 2

Medians and reciprocals of slopes of attainment lines of developmental stages of the hand, Dakar and Boston girls, 5 to 11 years

Osseous center	Stage (Greulich-Pyle 1950)	Dakar girls		Boston girls	
		Median age of onset in months	Reciprocal of slope in log units	Median age of onset in months	Reciprocal of slope in log units
Navicular	I	60	.09	51	.09
Lunate	III	60	.10	—	—
3rd middle phalanx	IV	60	.16	—	—
5th middle phalanx	IV	60	.11	—	—
4th distal phalanx	IV	60	.11	—	—
Lesser multangular	I	63	.10	54	.07
2nd distal phalanx	IV	63	.11	—	—
5th distal phalanx	IV	63	.11	—	—
Greater multangular	I	66	.10	51	.09
Navicular	III	72	.08	—	—
Greater multangular	IV	72	.08	—	—
Lesser multangular	III	72	.07	—	—
1st metacarpal	IV	72	.09	—	—
3er distal phalanx	V	72	.10	—	—
Lunate	V	78	.08	—	—
4th distal phalanx	V	78	.07	—	—
2nd distal phalanx	V	78	.07	—	—
Ulna	I	84	.06	72	.06
Greater multangular	V	84	.08	—	—
Lesser multanguler	IV	85	.07	—	—
Triquetum	VI	84	.07	—	—
5th distal phalanx	V	84	.07	—	—
Navicular	IV	96	.06	—	—
Ulna	V	102	.07	—	—
Capitate	VII	102	.11	—	—
1st proximal phalanx	IV	102	.07	—	—
2nd proximal phalanx	VI	102	.05	—	—
5th metacarpal	VI	120	.05	—	—
2nd middle phalanx	V	126	.05	—	—
3rd middle phalanx	V	126	.05	—	—
4th middle phalanx	V	126	.04	—	—
Pisiform		126	.06	102	.06
Lesser multangular	V	132	.07	—	—
Hamate	IX	132	.04	—	—
Navicular	VIII	132	.05	—	—
Greater multangular	IX	132	.05	—	—
1st metacarpal	VI	132	.06	—	—
2nd metacarpal	VI	132	.06	—	—
3rd metacarpal	VI	132	.06	—	—
3rd proximal phalanx	VI	132	.06	—	—
4th proximal phalanx	VI	132	.05	—	—
5th proximal phalanx	VI	132	.04	—	—
5th middle phalanx	V	132	.04	—	—

TABLE 3

Medians and reciprocals of slopes of attainment lines of developmental stages of the hand, Dakar and Boston girls, 11.5 to 15 years old

Osseous center	Stage (Greulich-Pyle 1950)	Dakar girls		Boston girls	
		Median age of onset in months	Reciprocal of slope in log units	Median age of onset in months	Reciprocal of slope in log units
Triquetrum	VII	138	.08	—	—
1st proximal phalanx	VI	138	.06	—	—
1st distal phalanx	VI	138	.05	—	—
3rd metacarpal	VI	138	.05	—	—
Radius	X	144	.03	—	—
Lunate	VI	150	.08	—	—
Ulna	VII	150	.04	—	—
1st sesamoid 1st metac.		150	.04	126	.04
2nd distal phalanx	VIII	180	.04	—	—
3rd distal phalanx	VIII	180	.03	—	—
4th distal phalanx	VIII	180	.04	—	—

In Dakar girls, the following stages have median ages of appearance greater than 15 years (180 months):

Radius XIII	1st proximal phalanx VIII
Ulna X	2nd-5th proximal phalanges IX
1st metacarpal IX	1st distal phalanx VIII
2nd-5th metacarpal VIII	5th distal phalanx IX

TABLE 4

Attainment lines of all centers in the three age-periods: distribution (%) of the reciprocal of their slopes (as measured, in log units, along the abscissa)

Reciprocal of the slope (log units	*Percentages within age-periods*		
	10 days to 5 years	*6 to 10 years*	*11 to 15 years*
.03-.05	0	21.7	63
.06-.08	8.1	65.3	36.4
.09-.11	44.9	13.0	0
.12-.14	20.4	0	0
.15-.17	8.2	0	0
.18-.20	18.4	0	0

Our first attempt at grouping separated the carpals from the epiphyses, since these groups had often been mentioned in the literature. This attempt failed. In none of the age-spans did significant differences between these centers appear, contrary to what Todd (1937) found on a sample of children from Cleveland, Ohio.

Instead, the clearest subgroups were found to be (a) the radius and middle and distal phalanges, and (b) the ulna, metacarpals and proximal phalanges, as shown in table 5.

Prior to six years of age, the variability of groupe *a* was very significantly greater than that of group *b* ($p < 0.001$ by the chi square test). From six to 10 years, no significant differences were observed between the groups by Fishr's test of significance for 2 × 2 contingency tables. From 11 to 15 years, however, the variability of group *a* became smaller than that of *b* ($p = 0.0.025$ by the Fisher test), a situation opposite to what had existed before six years of age.

The variability of the carpals did not differ significantly from that of subgroup *b* at any of the age-spans studied. On the other hand, the divergences from the situation in subgroup *a* were much as previously described for subgroup *b*. Before six years of age, subgroup *a* had a greater variability of borderline significance ($p < 0.05$, Fisher). No significant difference was observed from six to 10 years, and from 11 to 15 years, the variability of subgroup *a* was smaller than that of the carpals ($p < 0.05$, Fisher).

TABLE 5

The two groups of epiphyses
Distribution of the reciprocals of the slopes of their attainment lines
(cf. tables 1-3) at the three age periods

Reciprocal of the slope (log units)	Percentages within age-periods					
	10 days-5 years		6-10 years		11-15 years	
	groupe a	groupe b	groupe a	groupe b	groupe a	groupe b
.03—.05	0	0	42.9	33.3	100	44.5
.06—.08	5.2	11.1	42.9	50.0	0	55.5
.09—.11	15.8	66.7	14.2	16.7	0	0
.12—.14	21.1	22.2	0	0	0	0
.15—.17	21.1	0	0	0	0	0
.18—.20	36.8	0	0	0	0	0

group a = radius, middle phalanges, distal phalanges.
group b = ulna, metacarpals, proximal phalanges.

It is noteworthy that the carpals are not as unlike group *b* as the bones in group *a* are. This reduced significance explains why no differences appeared when global comparisons were made between the epiphyses and the carpals.

COMPARISONS BETWEEN DAKAR AND BOSTON GIRLS

Our next undertaking was a series of comparisons between the African sample from Dakar and a series of American White children from a longitudinal growth study in Boston (Stuart *et al.*, 1939). Data published on the Bostonian group include percentages of each sex who had passed the onset of calcification of some dozens of skeletal centers (Harding, 1952), tabulated by age. These percentages were graphed on attainment lines of a kind which could easily be compared with those for the children of Dakar.

This evidence permits three basic comparisons: the pattern of distribution of the different groups of centers from each other along the age axis, the median ages of onset in the two regional samples of children, and within each sex, the variability of ages of onset. As in the earliest section on the Africans alone, the results here deal only with the girls.

For the Boston girls, the distribution of attainment lines for the specific centers of ossification, as plotted on the logarithmic age axis, revealed that no difference appeared when global comparisons were made between the epiphyses and the carpals.

A difference was found, however, between the two subgroups of epiphyses which had been defined earlier for Dakar: the middle and distal phalanges and radius on the one hand, and the ulna, matacarpals and proximal phalanges on the other.

In the Bostonian sample, the reciprocals of the slopes of the lines representing the first subgroup varied from 0.08 to 0.13 log units (tables 1-3). The distribution for the other epiphyses ranged from 0.05 to 0.08 log units. In other words, the groups of osseous centers are less differentiated in Boston children than among the African girls from Dakar.

In considering the median ages of appearance of the osseous centers in the two groups of children, in 17 out of 18 sites seen up to 18 months of age, the African sample was more precocious than the American. This difference was highly significant by the Student-Fischer t-test for matched pairs ($p < 0.01$).

Between 18 and 24 months, the appearance of two centers had identical median ages in Dakar and Boston.

Subsequent to 24 months, the appearance of centers in the children of Dakar was relatively retarded, and the mean amount of retardation was one year. This aggregate of differences was highly significant ($p < 0.01$).

Comparisons of the variability of attainment of stages in the two groups of children revealed that prior to eight months of age, when the capitate and hamate appeared, no difference in variability was seen between the African and American groups.

From eight to 30 months, inclusive, the variability in the African children was considerably greater than in the Americans. This difference was highly significant ($p < 0.01$, t-test). Furthermore, this augmented variability was most evident in the group comprising the radius, middle and distal phalanges, which were significantly more variable at these ages than the other epiphyses ($p < 0.05$, Fisher). In other words, these two groups of epiphyses have more dissimilar variabilities in Dakar than in Boston.

After 30 months, the differences in variability between Dakar and Boston are insignificant, and in some cases are not evident.

As shown in fig. 2, the comparisons between the girls of Boston and Dakar may be summarized in a very simple scheme. Prior to eight months, when the two earliest carpals first appear, the African girls are precocious, but do not differ from the Bostonians in variability.

From eight to 30 months, when nearly all the epiphyses appear, and also the triquetrum, the Dakar girls are first precocious, then at the same level, then retarded. During all this period of deceleration, the variability of attainment of the stages is greater than in the American girls. In other words, this deceleration does not take place at exactly the same age in all the African children.

After 30 months, when the remaining carpals and the ulnar epiphyses appear, the girls of Dakar are retarded, but with the variability of attainment of initial formation of the various centers remaining close to that of the Bostonian girls. This augmented variability between eight and 30 months, more markedly elevated for some osseous centers than for others, results in a difference of pattern in the successive appearance of these centers.

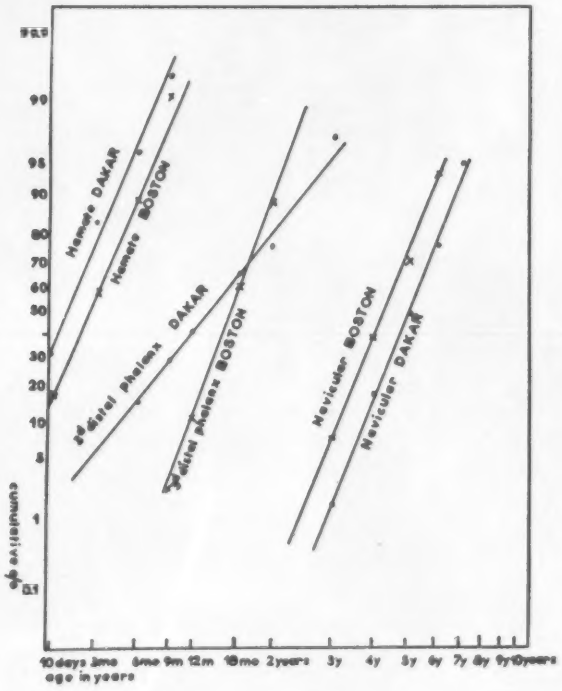

Fig. 2. Onset of Three Ossification Centers in Dakar and Boston (Girls):

Hamate (median age of onset in Dakar: 1 month);

3d distal phalanx (median age of onset in Dakar: 14 months);

Navicular (median age of onset in Dakar: 4½ years).

For some centers, this difference is insignificant; for others it is quite apparent: the first metacarpal appears at the same age as the second middle phalanx in Boston, while in Dakar it appears 10½ months later (table 1). Consequently, charts of appearance of osseous centers used in Boston cannot apply to children in Dakar during this age-span.

Among the boys in Boston and Dakar, much the same scheme applies, but at different ages. The period of deceleration, instead of being from eight to 30 months, occurs at 11 to 42 months.

OSSIFICATION IN DAKAR CHILDREN WITH KWASHIORKOR

A group of children from Dakar who were hospitalized for severe kwashiorkor were compared with the "normal" sample from Dakar which was described earlier. Forty-two of these cases, in whom the birth date was known precisely, have been analyzed up to the present. This small sample did not permit the differentiation of the group into males and females. These children ranged in age from one to three years.

In order to define possible effects of kwashiorkor on skeletal development in these patients, the normal sample from Dakar was used as the standard of reference. For each osseous center, the percentage of infants of the same sex in the "normal" population who were at each developmental stage permits the calculation of the number of ill cases who would theoretically be expected to be at this stage if their maturation were not disturbed by kwashiorkor.

Comparison of these theoretical percentages with those actually observed in the hospitalized cases might reveal the presence or absence of a significant retardation in these patients. On the other hand, the proportions of stages seen in each bone in the ill population permitted the calculation of its theoretical mean age of appearance, and consequently the mean retardation of each center.

This investigation revealed no significant retardation in the earliest carpal bones (capitate, hamate and triquetrum).

In the epiphyses of the long bones, all centers were significantly retarded except the distal phalanx of the thumb and that of the fifth finger. For our group *a* of centers (metacarpals and proximal phalanges), this retardation is particularly significant ($p < 0.001$, chi square). It is not quite so for group *b*—radius, middle and distal phalanges ($0.01 < p < 0.05$, chi square).

The degree of retardation in months is, on the average, as follows:

Radius	5.5
Metacarpals	5.5
Prox mal phalanges	7.5
Middle phalanges	4.0
Distal phalanges	6.5

Although the retardation of the metacarpals on the average is the same as that of the radius, and one month

less than that of the distal phalanges, the greater significance of the metacarpal retardation occurs because the variability of the radius and of the distal phalanges is greater.

DISCUSSION

In our population of children from Dakar, the differentiation of two groups of epiphyses obliges us to modify existing methods of assessment of skeletal maturation as defined on American and European children.

In the Oxford method, a score is assigned to each of the stages of each osseous center. Thus, the score 3, for a center, indicates that this center has arrived at the third of its succession of stages, arbitrarily defined. As a result, this score has no absolute value (Acheson, 1957; Tanner, 1960). As mentioned in the introduction, each center therefore is rated according to a ranking, or *ordinal* scale.

At a given age, if one combines all the scores for the different skeletal centers, one arrives at a broader ordinal scale. In effect, all the different stages of the different osseous centers can be classed according to the percentages of children who have reached these scores. The more the percentage of chidren at a stage is increased, the more obviously this stage represents a precocious level of maturation, and vice versa.

If such a scale is to be usable at all stages, all centers should necessarily appear in the same sequence or pattern in every child. In this case, the ranking of the different stages of all the osseous centers would not vary from one age to another. But we have just seen that in the Dakar sample the coefficients of variability are unlike in the different groups of centers. As a result, the slopes of the attainment lines of the groups are different, and these lines, instead of being parallel, cross each other.

As shown in figure 3, at two years, 8% of the children from Dakar have arrived at stage II of the fifth metacarpal, and 38% have reached the second stage of the distal phalanx of the thumb (a significant difference). As a result, at three years, stage II of the distal phalanx of the thumb represents a more precocious degree of maturation than does stage II of the fifth metacarpal, since the phalangeal center has begun to calcify in a larger percentage of children. On the other hand, at five years, the difference is reversed. Eighty-eight percent of children have reached stage II of the fifth metacarpal, while only 77% have attained stage II of the distal phalanx of the thumb (a significant difference). Now Stage II of the fifth metacarpal represents a more precocious stage of maturation than does the latter condition.

This scale of ranks is therefore inconsistent. Adding the scores of these two centers of ossification is therefore mathematically indefensible. At any rate, it is admissible to consider these centers separately, since they represent two types of development.

In the method of Greulich and Pyle (1959), skeletal ages are attributed to the different bones. These skeletal ages represent the interval of time elapsed since birth by the mode of the standard population used in defining their radiographic atlas. As a result, skeletal age ratings have absolute values, for which parametric statistics may be calculated such as the sum and the mean.

Here again, however, in calculating the mean of groups which have different developmental patterns, we risk the loss of important information. When comparisons are made with a standard population, a given advancement or retardation does not have the same interpretation for two centers of ossification with different variabilities of attainment. Thus, it would seem unwarranted, in our population, to arrive at a global expression of the skeletal age of the epophyses.

Continuing from the topic of norms or standards to the theme of variability in Boston and Dakar, it is noteworthy that in neither population is a clear-cut difference seen between the carpus and the epiphyses. It was this supposed distinction which led Todd (1937) to recommend that skeletal age be rated preferably from the epiphyses rather than from the carpals.

Instead, as in Dakar, the Boston children exhibit a difference in variability between the two subgroups of epiphyses: radius and middle and distal phalanges on

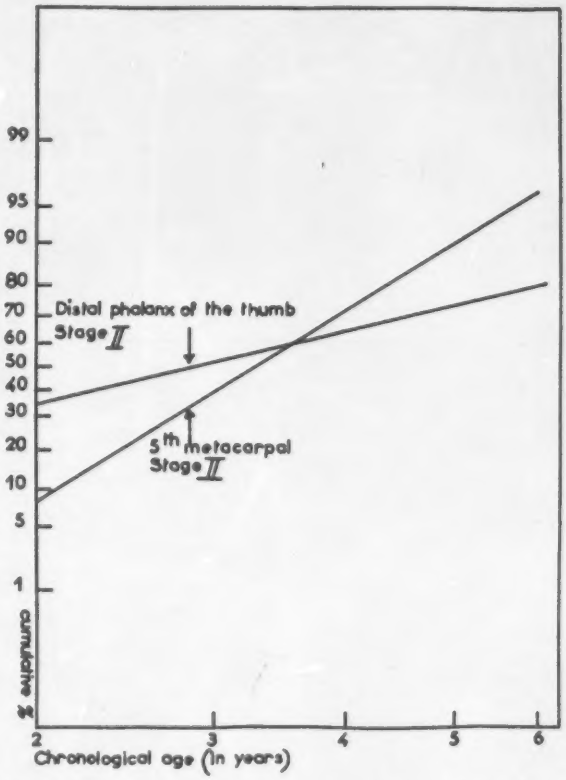

Fig. 3. Example of the Inconsistencies of an Ordinal Scale Obtained by Combining the Scores of Different Osseous Centers.

the one hand, and the ulna, metacarpals and proximal phalanges on the other. Nevertheless, this difference is less pronounced than in Dakar.

The data from Boston were gathered on children growing up during the 1930's. It is possible that such a difference in epiphyseal variabilities is no longer found in children living today in the highly developed nations. Comparative studies undertaken by the Centre International de l'Enfance should settle this question in the near future.

The precocity of African children in infancy has already been described (Falkner *et al.*, 1958). At present it seems impossible to state whether is was a purely genetic or largely environmental basis: *i.e.*, no study on African children has made controlled observations on this subject. Falkner conjectures that it could be produced by breast feeding.

The deceleration of ossification which occurs in the Dakar children after the first postnatal months illustrates strikingly the loss of vitality which has been found in other aspects of development at the same time: particularly the growth of body size and the maturation of psychomotor functions (Falkner *et al.*, 1958; Bardet *et al.*, Massé *et al.*, 1961). This phenomenon coincides with the end of lactation or weaning. During this entire period there is a wide prevalence of protein deficiency. About a third of the children in the longitudinal growth study at Dakar have exhibited at least one of the clinical signs described by Sénécal and Aubry (1958) as abortive protein malnutrition: typical disorders of the skin, changes of the hair, and localized edemas. This is also the period of onset of the parasitic infestations which begin when the child starts to crawl on the ground.

In the hand and wrist, this deceleration affects almost exclusively the epiphyses of the long bones in delaying their time of first appearance. After this critical period, no compensatory acceleration occurs, and the carpals which appear later do so at a retarded age.

In kwashiorkor, a still more extreme manifestation of this same pattern is seen. A clear-cut opposition is seen between the two groups of bones: the carpals and the epiphyses of the long bones. Only the latter show a significant retardation at the time of illness.

Parenthetically, however, comparisons of "normal" development in Boston and Dakar have been made differently from the study of the kwashiorkor cases. In these patients, development of the hand was only assessed at the time of illness. The normal comparisons could only be made for the onset of ossification of the different centers (stage I), but the time span began much earlier, and continued much later, than the critical malnutrition period for kwashiorkor. We have seen that during this critical period, the appearance of the epiphyses is progressively delayed in even the "normal" children of Dakar. Later on, the final carpals are also delayed. We do not know yet whether the two carpals which first appear before the critical period (capitate and hamate) are also delayed in their maturation later on, at the time when protein deficiency becomes manifest. A study is under way in Dakar to compare the children with clinical signs of deficiency with those in the same sample who are the best fed. This study should ascertain not only the onset of development of each center, but its subsequent rate of maturation as well.

During kwashiorkor, only the epiphyses could be shown to be more retarded than those of the "normal" children of Dakar. No roentgenograms have yet been made after recovery, and at present we are uncertain whether the later carpal centers might be likewise affected. At any rate, the different behaviour of the carpals and epiphyses at the time of illness adds a new element to this study.

Still another diagnostic refinement is the differentiation of the two subgroups of epiphyses, in which the metacarpals and proximal phalanges are more affected by kwashiorkor than are the remaining epiphyseal centers.

It is possible that a similar degree of retardation affecting groups of bones with different variabilities (here, for example, the radius and metacarpals), might arise from different causes. Finally, a similar degree of retardation affecting centers of different variabilities will not necessarily have the same statistical significance. In the litterature, too often the retardation of different groups of bones is described without reference to their dissimilar patterns of variability.

SUMMARY

The present study is a test of whether current methods of qualitative assessment of skeletal maturation in the hand can be applied without modifications to a population of West African children in Dakar. This problem has two aspects: whether each skeletal center has the same sequence of stages in White American and Senegalese Negro children, and whether the same subgroups of centers can be discerned in both populations.

It was found that the sequences of stages within centers were nearly all alike in the two populations. The more complex problem of subgroups and patterns of development of centers was approached by three distinct methods: (1) a study of the variabilty of attainment of the different stages of development of each ossific center; (2) a comparison of the onset of calcification of each center in the Dakar sample and in a group of children from Boston; and (3) a study of skeletal maturation in children from Dakar who were seriously ill with kwashiorkor.

The data indicated that in Dakar three different groups of skeletal centers could be discerned in the hand: (1) the carpals, (2) the radius and middle and distal phalanges, and (3) the ulna, metacarpals and proximal phalanges.

The most meaningful procedure for evaluating skeletal maturation would seem to be to rate the three groups separately. In studying retardations brought about by pathological conditions, we must take account of the different variabilities of the three groups.

Four additional findings in the present study seem to deserve more detailed consideration. The evidence on the variability of attainment of the stages in the different skeletal centers revealed three chronological phases. In the girls of Dakar, the earliest phase is prior to six years of age. The se-

cond extends from six to 11 years, and the third from 12 years onward.

Comparisons of the time of onset of calcification of centers in the hand in the Dakar and Boston growth studies revealed a precocity of development in the African infants in the first months of postnatal life, followed by a deceleration, and finally a retardation in middle and late childhood.

Studies of the variability of attainment of stages of development in the different centers in the Boston sample revealed that two groups of epiphyses are distinguishable, much as in the Africans. A similar phenomenon may occur in other populations, and again may call for appropriate modifications of existing methods of evaluating skeletal development.

Finally, patients with severe kwashiorkor present a retardation of skeletal maturation which is significant only for the epiphyses of the long bones—at least, during the acute phase of the disease.

ACKNOWLEDGMENTS

The senior author gratefully acknowledges her indebtedness to the Centre International de l'Enfance, under whose auspices this study was carried out and under the direction of Dr. J. Sénécal. In Africa, Drs. P. Cantrelle and H. Dupin contributed data. The findings on Boston and normal Dakar children were partly analyzed during a Research Fellowship at the Harvard School of Public Health. At Harvard, the following contributed greatly to this enterprise: Drs. E. A. Fanning, L. Lebret, S. I. Pyle, and R. B. Reed. This research of the junior author was carried out during the tenure of a Research Career Development Award, U.S. Public Health Service.

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89

Gesell tests on African children *

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It is our purpose to describe the results of the examination by Gesell tests of 183 African children betwen 1 and 72 months of age, seen in Kampala or in the country districts around. The work has not been continuous, but has been carried out during three separate visits by one of us (M.G.), each from July to September, in 1954, 1955 and 1956. In 1954, a study was made of the psychologic changes accompanying kwashiorkor in children admitted for treatment to the hospital wards of the Infantile Malnutrition Group. The disease is most prevalent in Uganda during the second year of life, probably because the diet given at weaning is inadequate, and a control group of well-nourished children of the same age was examined at the same time as the children in hospital. It was found that most of the healthy children were precocious in their psychomotor development, and that the precocity was greater the younger the child, but that towards the end of the second year it tended to diminish. Younger and older children were therefore tested, and it is now possible to present results for 183 children, of all the ages covered by the development schedule of Gesell: that is, of all ages from 1 month to 6 years. The results are suplemented by an account of findings on 113 newborn children, who were examined by the method described by André Thomas.

CHILDREN STUDIED

The children were obtained in various ways. One group was seen in the building of the Infantile Malnutrition Group, at Mulago Hospital, Kampala, the largest general hospital of the Medical Department of the Uganda Government. They numbered 43, and had been brought to hospital for the treatment of some minor and unimportant illness, or merely to accompany other members of their families. Another 15 children were examined at the Group's Child Welfare Clinic, in a country district about 16 miles from Kampala, and 12 more at a Child Welfare Clinic in the labor lines of a large agricultural estate, also in a country district, and about 20 miles from the town. Forty-five were seen in their own homes in villages a few miles outside the town, and 68 in a kindergarten at a Theological College, 13 miles from Kampala, where their fathers were training for ordination.

The advantages of a longitudinal study were realized, but for various reasons such a study could not be carried out fully, but 51 children were seen twice in successive years, and 5 were seen three times. Nearly all were children of the theological students or were those who had been seen in their village homes.

The amount of contact with Europeans, the educational level, the social status and the economic circumstances of the families varied considerably, and most classes were represented except the highly educated—none of the parents had been students at Makerere, the University College of East Africa, or at any other University—and the most wealthy. The agricultural laborers, most of whom belonged to the Wakiga tribe of south-western Uganda, had the least knowledge of Europeans and their ways, and were the poorest. The families whose children came to hospital, those seen at the Group's Welfare Clinic, and those seen in their own village homes, were nearly all of the Ganda tribe, which inhabits the district around Kampala, and were mostly small holders who could afford more than the bare necessities of life, and were in fairly comfortable circumstances. The villagers were selected originally by their local chief to take part in a socio-anthropologic investigation to which the Gesell tests were added. They were selected because the chief believed that they would collaborate well, and they were probably above the other Ganda in general intelligence; most of the fathers had well-paid work in Kampala, and some only returned to their homes at week ends. The theological students had probably had the best schooling of all the fathers, although their wives were mostly less well educated; they had little money, but were well housed by the Theological College, had adequate cheap food, lived as a community and were well accustomed to Europeans. Nearly all were of tribes other than the Ganda.

None of the children examined was suffering, so far as could be ascertained, from any illness likely to affect his performance in the test. If a child due for a test was found to be unwell, the test was postponed until he was better.

CONDUCT OF THE TESTS

The Gesell technique as used in Paris[3] was used without any important modification, except that the child, his mother and the examiner all sat on the floor. Forty of the examinations, and those all of children more than 2 years of age, were carried out by an African assistant who had watched many tests, had been carefully instructed, and had an excellent understanding of the principles involved. The 40 examinations were, however, done under the observation of one of us (M.G.) who herself carried out all the test com-

* We acknowledge the permission granted to reproduce this paper appeared previously in Pediatrics 20 (6): 1055-1065, Dec. 1957. Copyright American Academy of Pediatrics. 1957.

pletely. The mothers attended all the tests except those on the kindergarten children, for which the teacher was present.

The conditions for the test were best in the hospital where a room in the Group's building could be kept free from disturbance, and in the village homes, where peaceful rooms could usually be found, although in some of them visitors were likely to appear and to interrupt the proceedings with the interminable greetings that are essential for politeness, and by laughing at the children. They were worst at the agricultural estate, because it was impossible to prevent spectators crowding the windows of the clinic room and making continuous comment. They were fairly good at the Theological College, where a large hall was used, but as the hall had open sides the children were distracted occasionally by passers-by.

The test was always preceded by the exchange of a few words with the mother and child, to put them at ease. The child usually sat between the mother and the examiner. The examiner was a little way behind the child, in which position he could make use of her, or not, as he desired. The same order of examination was always followed. For children under 6 months the order was: rattle, ring, cubes, cup, bottle and tablets, bell, ball, mirror and tests of motor activtiy. For older children it was: cubes, cup, bottle and tablets, form board, book, pencil, questions, ball, steps and mirror. A few minutes were allowed if necessary at the beginning for the child to make himself familiar with the material, and if he did not perform a test spontaneously, he was encouraged verbally, and sometimes by example. The test usually took between 45 and 60 minutes. It was completed by questioning the mother about the previous history of the child, about his present behaviour and about his environment, and also about the other children in the family. It was preferable to do the questioning after the test, and not before, because the child was not then kept waiting, and the mother was to some extent prepared. Nearly always, the questioning had to be done through an interpreter.

Over a hundred of the tests were photographed with a high-speed flashlight which never caused any discernible upset to the child. For many of the tests, the number of photographs was large enough to record the whole sequence. The photographs could sometimes be used to confirm the written description of the tests and at all times made a permanent and unequivocal record.

RESULTS

The analysis of the results was qualitative as much as quantitative; the behaviour of the child, the way he set about the tests, and his ability to make contact with the examiner, were all considered as carefully as the failures or successes in performance.

From the first, the precocity of psychomotor development was obvious and striking. It was found in all the group of children, and whatever the conditions of the examination. Most of the children accepted the test situation immediately, were interested in the material, and passed easily from one performance to another, but did not object when the material was changed, or when it was finally put away. Their attitude was all the more remarkable because most of them could never have previously handled anything like the material. A few of the older children, especially some about 4 years of age, turned to the examiner as though asking for approval before taking the first objects. A word of assurance was all that was needed for the child to start the test, and after that the sequence was uninterrupted. The results have been set out by age, in divisions corresponding more or less to the ordinarily-accepted "milestones" of development: For instance, the first ending at 6 months when standing began and the next at 12 months to correspond with walking. For each age, motor activity (bodily movement, locomotion and prehension), intellectual development (with special reference to *adaptivity*, the term used for a combination of motor and sensory development, ability to concentrate, to observe, to imitate, to remember, and to make a synthesis of experience) and affective development (the relation of the child to his parents, to other people and to his surrounding) have been described.

Children 1 to 6 Months of Age

There was remarkable precocity of motor development. From the first month, when the child was put on his back, he held his head in the mid-line. When he was drawn up by his hands into a sitting position, there was no "head-lag", and when he was held sitting, his back was straight and his head was stable. At 3 months in some children, but in more at 4 months, sitting unsupported for a few seconds was possible. At 5 months the sitting position was fully achieved: The children could remain sitting for half an hour or more, could lean forwards at will and sit up again. The children liked to be stood up, and very early, sometimes in the first month when they were drawn into the sitting position they went further and became erect and could remain momentarily standing, raising and putting down one foot. From 2 months they could support, when standing, the greater part of their weight; at 4 months they could stand if they were held by their two hands, and a few of them if they were held by only one hand. At 6 months they could stand by themselves against a support. Standing was tested in this way: They were shown the ball, and it was put into the Gesell box; they would then try to raise themselves, sometimes looking for help, sometimes alone, and would finally reach a standing position holding on to the box. Sometimes they held on by only one hand whilst they used the other to point at the ball.

Prehension could be tested even in the first month, because the hands were already half-open and the eyes followed movements closely. The various stages of prehension—cubito-palmary, palmary and radio-palmary—which could be very well studied with the cubes, were passed through rapidly. The children were very interested in the test material, and always tried to pick it up.

At 5 to 6 months they could pick up an object between the thumb and the other fingers held together, and with the thumb opposed to the fingers and not beside them, and they could let go at will. From the age of 3 months, they took a lively interest in everything around and this, and their motor ability, and their pleasure in making contact with the examiner, allowed the usual performance of many tests that European children of the same age could not accomplish.

Thirty-three children were examined, and the Gesell quotients were as follows: (For those unfamiliar with the Gesell scores, it may be helpful to add that 100 represents the average performance of an American or European child at the age in question.)

Motor activity: usual score about 140, none under 100, the range 106-345
Manual ability: usual score about 130, one under 100, the rest 109-360
Adaptivity: usual score about 120, one under 100, the rest 104-275
Language: usual score about 120, one under 100, the rest 100-300
Personal-social behaviour: usual score about 120, three under 100, the rest 100-250
Quotient for general development: usual score about 130, none under 100, the rest 110-260

The younger children—those up to 16 weeks of age—had high quotients for motor development and somewhat lower quotients for adaptivity. The older children—those who were 17 to 26 weeks of age—had quotients for motor development that were slightly lower, but were still high, and their quotients for adaptivity were raised to be equally high. The equality gave the test homogeneity. In the group as a whole, interest was especially great in the examiner and in the mirror, and after them in the bell.

Children 7 to 12 Months of Age

At 7 months the children could stand without support, at 8 months they began to walk, holding on to the wall, and at 9 months they took their first steps alone. At 10 months they could walk well, but with a certain stiffness, and at 1 year they could run. Manual dexterity continued to develop and at 10 months they could take a tablet between the thumb and index finger. At 12 months they could take objects perfectly between the pulps of these digits, whilst the others were held separate and step-wise. The economy of movement was especially notable, as well as this extreme precision. The harmonious development that was first recognized between 3 and 6 months lent homogeneity to the test, and the motor development was paralleled by adaptivity, language and personal-social behaviour. In 34 children who were examined the quotients were consistently high.

Motor activity: usual score about 135, one under 100, the rest 100-150
Manual ability: usual score about 125, two under 100, the rest 106-165
Adaptivity: usual score about 125, two under 100, the rest 100-160
Language: usual score about 120, five under 100, the rest 100-150
Personal-social behaviour: usual score about 120, one under 100, the rest 100-148
Quotient for general development: usual score about 130, two under 100, the rest 102-145

It was particularly the cubes that pleased the children and they liked to exchange them with the examiner.

Children 1 to 2 Years of Age

At this age the precocity tended to be lost and a certain stagnation began to appear. The rate of development slowed down, so that only about 9 months' progress, by European standards, was made in the year. The slight progress made in language was especially notable. On the other hand, the average child was starting to eat alone, was dry and clean, and was already beginning to imitate his mother. He was however very dependent on her, and it was obvious during the test that his need of her was greater than the need of a younger child would have been. He established contact with the examiner less rapidly, and tended to give objects more to his mother than to the examiner. He was particularly interested in the tablet and the bottle, and liked to go on repeatedly putting the tablets in and out. Another great attraction was the book, and he liked to caress the pictures. The quotients, although falling, were still mostly above the average for European children. Fifty children were tested.

Motor activity: usual score about 110, 9 under 100, the rest 100-150
Manual ability: usual score about 110, 5 under 100, the rest 100-150
Adaptivity: usual score about 105, 7 under 100, the rest 100-148
Language: usual score about 100, 24 under 100, the rest 100-125
Personal-social behaviour: usual score about 110, 9 under 100, the rest 100-138
Quotient for general development: usual score about 110, 10 under 100, the rest 100-132

Children 2 to 3 Years of Age

In this age group, it was necessary to consider separately, for many purposes, the kindergarten children and the rest.

Motor ability was fully developed. At 2 years, not only could the child run well, but he could go up and down the steps alone and with one foot on each step, and could jump from the last. He could also stand momentarily on one foot. Manual dexterity was surprising and prehension was rapid and sure, so that all the 10 tablets could be put into the bottle in less than 20 seconds—an accomplishment of the European child at 4 years. Even in these motor tests, however, there was a difference between the kindergarten children and the others. The

kindergarten children quickly grasped what was wanted of them, but the others were much less understanding. For instance, before they would stand on one foot, a number of demonstrations was usually necessary. They found the tablets and the bottle very attractive, however, and when asked to put the tablets into the bottle as quickly as possible, they did so eagerly. There was little noticeable difference in the use of right and left hands. Some of the children took 15, 17 and 20 seconds to put in all the tablets with the right hand, and 17, 20 and 24 seconds when they used the left. About one-third of the children were left-handed.

The children who were not in the kindergarten were very dependent on their mothers and turned to them during the tests for encouragement or approval. Their interest in the material was less, and less well-sustained, than that of the kindergarten children, who succeeded better in the tests that showed adaptivity, and whose tests as a whole were more dynamic and quicker finished.

In one respect, there was no difference between the two groups: There was general acceleration in the development of language, more in comprehension than in expression.

As at the previous age, performances of the various components of the test were very even.

There were 36 children of this age.

Motor activity: usual score about 120, 9 under 100, the rest 100-137

Manual ability: usual score about 110, 9 under 100, the rest 100-131

Adaptivity: usual score about 100, 15 under 100, the rest 100-125

Language: usual score about 90, 28 under 100, the rest 100-130

Personal-social behaviour: usual score about 110, 9 under 100, the rest 103-159

Quotient for general development: usual score about 105, 9 under 100, the rest 101-135

Children Over 3 Years of Age

The difference between the kindergarten children and the others was more accentuated after 3 years of age. Of the 13 village children, only 3 seemed really to be interested in the test and eager for it, and all 3 were the children of teachers. The seven children seen at the hospital or the clinic all had development below normal for their age, except for the motor tests, and only in expression did they continue the progress that was first shown at about age 2½ years. On the whole these 20 children did not adapt themselves to the turning of the form boards, as if their appreciation of shape was defective. They placed the round block time after time in its former position, and tried by various means to force it into place. They were also unable to make steps or a bridge with the cubes. The kindergarten children not only made the steps and the bridge, but had a much greater interest in all the objects, carried out their performances more rapidly, showed better comprehension and were more varied in their expression.

The kindergarten children gave names to the things they drew, and most often spontaneously drew a motor car, which they always began with the wheels. The others did not name their drawings; they scribbled spontaneously and roughly imitated, or copied more or less, what they were shown. In front of the mirror, the kindergarten children recognised themselves at once and at once began to describe what they could see, but the others remained fixed, and usually silent, although some finally managed to name something. The kindergarten children had a more extensive vocabulary, and could name nearly all the animals in the book that was being used (*Père Castor's Farm*) although most of those animals were different from anything they could have seen. They not only named the goat, which is common in Uganda, but also named animals such as the horse and pig that they could have known only from pictures. They could distinguish between horse and donkey, and between several kinds of bird, and one child even recognised a peacock. The other children had only two names for everything—*goat* for all the fourfooted beasts and *chicken* for all the birds.

Thirty-one children were tested.

Motor activity: usual score about 108, 12 under 100, the rest 100-142

Manual ability: usual score about 108, 11 under 100, the rest 100-156

Adaptivity: usual score about 95, 42 under 100, the rest 100-142

Language: usual score about 95, 26 under 100, the rest 100-136

Personal-social behaviour: usual score about 100, 23 under 100, the rest 100-142

Quotient for general development: usual score about 100, 34 under 100, the rest 100-142

Children Who Were Tested More Than Once

Figure 1 shows the general quotients for development of those children who were tested in 1955 and 1956, and who were under 4½ years of age on the second occasion. It is clear that the repetitions gave results identical with those of the transverse study, and that the rate of falling-off was rapid in the first year, and slower afterwards.

The figure, because it expresses averages of all the components of the tests, does not show the fall in the language quotients already described that was first noticed between 1 and 2 years, and the subsequent partial recovery of those quotients.

Newborn Children

A series of 113 newborn African children were examined during 1956 at Kampala by the method of André Thomas and Saint-Anne Dargassies. Although the method is largely concerned with the determination of the degree of muscular tone and the eliciting of "primitive" reflexes, many of the details are carried over into the Gesell tests for children 4 to 8 weeks of

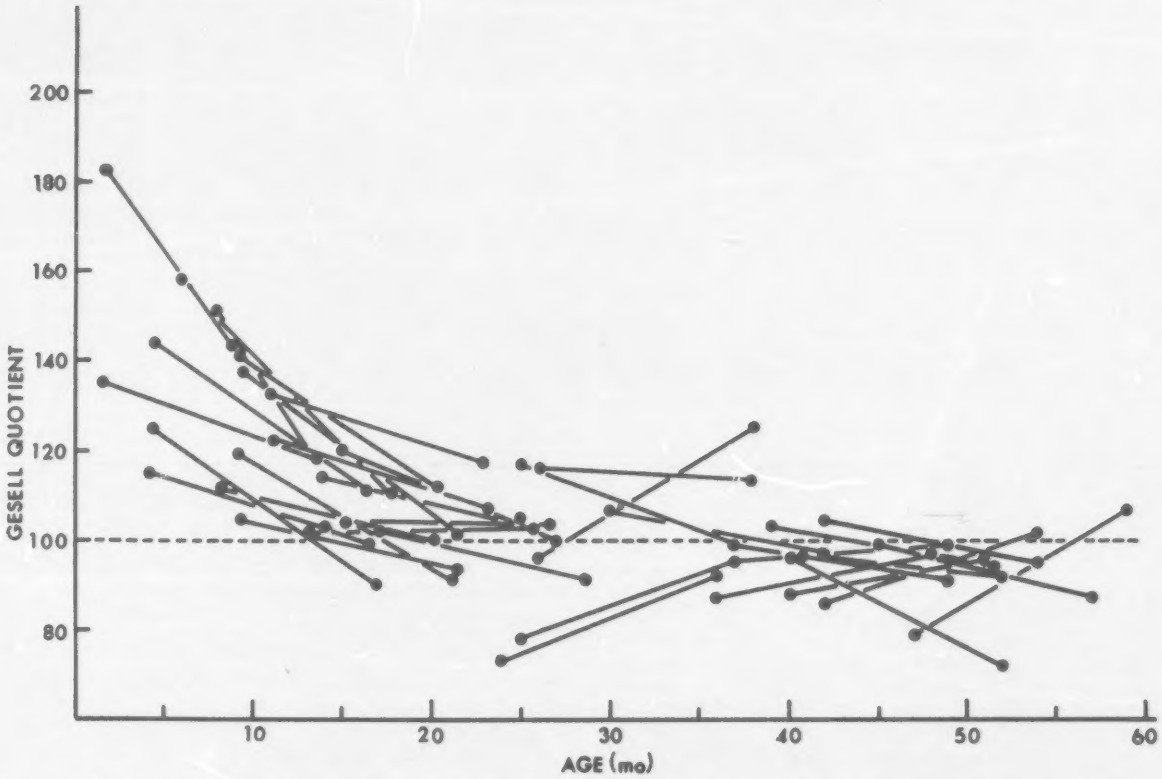

FIG. 1. The Gesell quotients for general development of children who were tested in successive years. The quotients usually fell as age increased.

age, or even older. For instance, in both examinations attention is paid to the attitude adopted by the child when he is placed on his back, to the carriage of the head and the straightness of the back when he is drawn into the sitting position, and to the way in which the fingers are held, or resist extension.

The findings on the African children have been described elsewhere. They can best be summarised by saying that they showed development that is, to say the least, highly unusual in European children at birth or in the first weeks of life, and the African children in fact behaved much like European children 3 to 4 weeks of age. They were not only less hypertonic in their flexion, but had a remarkable control of the head, and many of them could even raise the chin completely free of the table when they were lying on their fronts. Few showed the primitive reflexes after the first day or so of life, even the near-convulsive Moro reflex-usually a very consistent finding in European children—being found in only 6 of the 79 children more than 24 hours of age. The well-known grasp reflex, which enables the European child to suspend himself from a stick in a somewhat simian manner, was feeble and poorly-sustained, and automatic walking was rare. Children only 2 days old were able to follow movement with their eyes, and some appeared to be able to focus.

A stuy of the African child at birth, more detailed and exact than was possible for this series, would probably show a large number of other points of difference from European children. No explanation was offered for the precocity, but it was fairly clear that it had a genetic basis. There was, unfortunately, no way in which the length of gestation period could be determined. The dates of the last menstruation were not accurately known.

DISCUSSION

The results of the examination of the newborn children were consistent with the results of the Gesell tests. From birth, the muscular tone of the African infant is different from that of the European, and the head is held better. The lesser degree of flexion may explain why there is in the African earlier standing, prehension and manipulation.

At every stage of development it was necessary to take into account the manner in which the children

were reared. Four infants, one aged 3 weeks, twins aged 20 weeks and one aged 27 weeks, were treated in the European manner—that is to say, were fed "by the clock" during the day and not fed at night, were allowed to lie in their cradles almost the whole of the 24 hours and were lifted only for feeding and for toilet purposes. The infant 3 weeks of age, when drawn into the sitting position, could not hold his head up, had a marked kyphosis, and when held horizontally on the examiner's hand, face downwards, could not raise his head. His hands were half-open, this being the only precocity he had in common with the other children of the same age. The twins were girls who had weighed 3.64 and 4.10 kg at birth; their physical appearance was excellent, they had a bright look, and their smile showed the liveliness of their interest, but their development, according to the Gesell standard, was that of infants of only 23 to 24 weeks, giving a general quotient of 118. An infant 19 weeks of age, chosen from the records merely because he was nearest in age, and in no way exceptional among African children, had development corresponding to 36 to 38 weeks, which gave a general quotient of 188. The two infants next in age (21 weeks) had quotients of 171 and 178.

The continual carrying on the back by the mother may strengthen the child's innate ability to hold his head firmly, by forcing him to compensate for her various movements. In the same way, his sitting position on her back, with his back straight, and his legs pressing against her waist, may help him to sit alone earlier than the European child. He is always with his mother when she goes to the fields, or to visit her neighbours, and his life in the changing scene is more stimulating than that of the child who remains in his cradle. The greater stimulation and the constant meetings with other people may account in part for the precocity of his interest in his environment, and his good contact with the examiner. Another asset that may help to make him so lively and interested, and so much at ease with a stranger—nearly all the children smiled at the examiner and caressed her face—is the perpetual comfort in which he lives. He is fed on demand, given the breast at the slightest cry, is always with his mother who is always ready to satisfy his every want, is in intimate contact with her, often with his skin touching hers, and sleeps with her. She introduces him very early to toilet habits, but at first only by holding him out, and she shows no sign of being upset if he fails. There is no forbidding, no refusal, no punishment for the African infant, and when we went into the homes the first thing the mothers did, after the usual formal greetings had ended, was to offer us their babies. It was their usual gesture to all visitors; it was noticed during the examinations that if a visitor were to arrive a baby would always be offered in the same way. The child would remain on the knees of the person to whom he was given, tranquil, at ease and cheerful; from the age of 3 months he would smile at that person and show his pleasure by gurgling and by his lively movements. If finally he began to whimper, the mother took him back immediately and put him to the breast.

The mother begins to offer food besides her breast milk at about the age of 6 months, but continues to give the breast on demand and to sleep with the child. The date for complete weaning is decided arbitrarily. The decision made, not only does she stop breast feeding, but she no longer carries him on her back, or sleeps with him, no longer consoles him, but laughs at him if he cries or merely tells him to stop crying. She teaches him to stay quiet, and especially to sit without fidgeting or speaking when a visitor comes. This method of education may explain the remarkably silent behaviour of the older children who happened to be present when the younger ones were being tested. They took part in the test completely passively, watching but making no movement towards the test material and without interfering in any way. When they were tested in their turn, they always sought the approval and permission of the mother.

Afer the age of 2 years, it is exceptional for the African child to have an adult treat him as though he was of any importance, or play with him. He has lived in a warm friendly world, but now finds himself in the cold. The only thing that his mother asks of him is that he should help her, without thanks if he does what he is told to do, and very often he must fetch and carry for the younger infant who now has the comfort that once was his. Thus, although it is the custom that in the first year the child should be satisfied completely, should be made the center of importance, and should be offered to every visitor, it is exactly the opposite in the second year, in which very little attention is given him, in which answers to his questions will be refused and he will even be forbidden to speak.

Even more, weaning is often reinforced by geographical separation. It is another custom to send the child to a grandmother or an aunt, to honour her, or to get him out of the way. Very often the substitute for the mother does not know the child at all, and lives so far off that the mother cannot come easily or often to visit. The custom has already been described in an account of the psychologic changes accompanying kwashiorkor, and has been related to the separation of European children. This year, two of the children examined last year, when they were both about 15 months old and who had since been separated from their mothers, were examined again. One was living alone with a grandmother, and the other with an aunt who had other young children who were already as much as she could manage. The grandmother and the aunt both told us that all was well, but both had noticed something unusual: The grandmother said that her child had been difficult to feed in the first 3 to 4 months and had slept a great deal in that time, and the aunt said that the other child still very often refused to eat altogether. One of the children, a boy, had been separated for 6 months, and the other, a girl, for 8 months. The boy had slight edema of the dorsum of the feet, and hair that was almost red, but his test showed no difference from that of the year before (the quotients were 104 and 102). The girl was thin, her hair pale, and her look vague; her test was extremely slow, and the quantitative result gave the very low quotient of 72. The year before, when she had been with her mother, the quotient was 109.

The result for the boy, showing no fall in the quotient despite the separation, was at first surprising. There was, however, another child left with the mother who had been tested in 1955 and found to have a quotient of 96. He was tested again and his quotient had fallen to 72; he was very inhibited, and was continually being bothered by the mother during the test. It seemed, then, likely that the boy who had been separated had in fact benefited by the separation, and had found, with his grandmother, a more satisfactory relationship than he could achieve with his mother.

Two African women, one a nurse in the Maternity Department of the hospital and the other a deaconess in training who had been a school teacher, told us without being asked that they had noticed how children changed when they were separated. They thought that the custom was applied to 90 % of the Ganda children, but to a smaller percentage of children of other tribes. The fact that the theological students were mostly non-Ganda may have been one of the reasons why there was less falling-off in the quotients of the kindergarten children.

It was obvious to us that in the children over 3 years there was a great difference between those who were given the opportunity to learn, and those who were left to pick up what learning they could. The three children of teachers seen in their homes have already been mentioned. They were considerably in advance of other children of their age, and of the rest of the children it was only those of the theological students who were really at their ease in the tests, were keenly interested in the material, and had a direct contact with the examiner. If the test objects were unfamiliar, they were accustomed to the other material offeed in the kindergarten, and were also accustomed to communicate with adults. Some of these children, but none of the rest, when we asked questions to which they did not know how to reply, asked us what we meant.

The kindergarten children had many advantages, but it is doubtful if their parents were of a higher social standing or were more intelligent than the parents of the village children. It seemed that it was not the parents that made the difference, but the way in which the children were reared. There is nothing surprising in the fact that a child asked constantly to exercise his capacities of observation, of imitation, or reasoning and of memory, and who is allowed to ask questions, will have better success in a test of intelligence than a child who had constantly been told to keep quiet. The memories of some of the children of 5 years, who were 4 years of age when they were seen last year, were surprising. They had been asked to make the steps with the cubes—a performance expected at 5 years—and could not do it. This year they made the steps spontaneously, as soon as the cubes were offered. Although most of them gave no explanation, two said they were doing it because we had asked them last year.

For the children from 4 to 6 years the Gesell tests were used although they are less satisfactory for children of that age than for younger ones. We have collected drawings from these older children on which we hope to report at a later date. We have already emphasised the importance of the ears in the drawings of a man and speculated on the relation of the importance to the African way of life, which is founded so largely on oral tradition and communication.

The Applicability of the Gesell Test to the African Infants and Children

The material of the Gesell test was very attractive to the African infant. The tablets and cubes were excellent for the study of manual ability, and the possibility of construction with the cubes, and the form board, were very apt for the exploration of ideas of shape and form. The material also helped in appreciation of the affective structure of the infant, an inhibited one choosing the things that were less brightly coloured and shiny, and a happy one preferring the red cubes and the ball. The mirror, which was used extensively, was of course especially important for children who were unaccustomed to it. Personal-social behaviour could not be adequately explored by the Gesell schedule in its present form. Eating with a spoon, lacing shoes and recognising coins are not the best of tests of a child in Uganda, and some adaptation is called for. The extremely advanced development of motor activity suggested that other modifications might be necessary, for the first year of life, and especially for the first 6 months. A level of development of 12 weeks found for an infant of 4 weeks indicates that the test is not altogether appropriate.

We regard our work as being no more than a preliminary to a complete study, and believe that it should be reported on a much larger number of children, of different tribes in Uganda and of different countries in Africa. The basic finding of precocity, especially in the younger children, will probably be constant—similar precocity has been observed in Dakar by Faladé[8]—but there will undoubtedly be local variations, some determined genetically and some by environment. The mode of production of the variations will be worth special investigation which will probably require the co-operation of physiologists and social anthropologists, amongst others.

An experimental study of the possibility of preventing the loss of precocity might be the most fascinating of the many lines for future work suggested by these results. Because of its potential value to the African, such a study might also be by far the most important. If it could be undertaken immediately, it might help to ease some of the difficulties that are becoming acute in the present period of rapid transition from illiteracy to higher education. At the moment, in East Africa and in most other parts of the continent, it is only the very exceptional student who is ready for university education at 18 or 19 years, the usual age for entrance to a European university, and anything which could accelerate the earlier training is greatly to be encouraged.

SUMMARY

The results of a series of Gesell tests on African infants and children are presented.

The most remarkable finding was the precocity of the younger infants. The motor development was greatly in advance of that of European infants of the same age, but was not an isolated phenomenon; it was paralleled by advanced adaptivity, language and personal-social behaviour.

The precocity was usually lost in the third year, but was retained by some children who had the advantages of a kindergarten.

The results of the Gesell tests were confirmed by a study of newborn African infants, whose state of development was also precocious by European standards.

The findings are discussed in relation to some details of the African environment, and especially to some local customs which may affect early development. Emphasis is placed on the potential value of finding means by which the early precocity could be maintained.

ACKNOWLEDGMENTS

We wish to thank M^me^ J. Aubry for her encouragement in this investigation and for the benefit of her experience of the effects of separation.

The expenses of the investigation were paid from grants made by the International Children's Centre, Paris, and the Mental Health Section of the World Health Organization, Geneva, and we wish to express our thanks especially to Dr. Maurice Gaud, in charge of the African affairs of the Centre, and to Dr. Ronald Hargreaves, formerly Chief of the Section.

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An analysis of individual patterns of DQ and IQ curves from 6 months to 17 years *

C. B. Hindley and C. F. Owen

The case is made for basing the analysis of longitudinal measurement data on each individual's array or curve of scores, and employing methods of analysis which take account of the shape of each individual's curve. DQs at 6 months and 18 months, and IQs at 3, 5, 8, 11, 14, and 17 years were available on 84 subjects from 6 months to 17 years, and 109 subjects from 6 months to 14 years, from a London longitudinal project. Scores at each age were converted to SD scores with M = 0, SD = 1. Polynomial equations were fitted to each subject's curve over the periods: 6 months - 17 years; 3 years - 17 years; 3 years - 11 years. For the whole sample the fitted curves yielded highly significant error reduction across all periods, thus rendering untenable the doctrine of IQ constancy. Over 6 months to 14 years, 54 per cent of subjects' curves had a significant fit. Curves differ not only in linear slopes, but in degrees and forms of curvilinearity, particularly over longer periods. A visual method of classification of the curves is also presented, which proved effective.

Implications of the findings are discussed, including that changes in IQ scores cannot be regarded as random variation, but as following systematic trends which differ between subjects; the need to regard isolated IQ measures on a subject as derived from a curve of unknown shape and slope; and the dangers of treating as equivalent IQs of subjects at different ages. It is concluded that the present methods of analysis are applicable to a variety of longitudinal measurement data.

A prime consideration in studying the development of any measurable characteristic is to employ methods which serve to reveal, rather than conceal, the course of change in individual subjects (Hindley, 1972; Wohlwill, 1973). As long ago as 1931, Merrill showed how the averaging of growth curves produced a distorted picture of what could be seen in individual growth curves, and a few years later Shuttleworth (1937) convincingly demonstrated the way in which a mean curve of increments of height against age serves seriously to obscure the phenomena of the adolescent growth spurt, visible in individual curves. It was obvious from the latter that peak growth rate occurs at different ages in different subjects, something which cannot be deduced from the mean curve. Furthermore, by ironing out differences in the individual curves, the mean curve seriously underestimates the peak amplitude of rates of growth in individual subjects, and, for the same reason, overestimates the duration of the phenomena. From the same studies, Dearborn & Rothney (1941) showed, again by presenting curves of individuals' measurements against age, that—whether height or IQ was the object of study—individuals sharing the same score at a chosen age displayed widely different trends of previous and subsequent scores.

Such findings have led to a considerable degree of recognition of the need for studying individual curves, among investigators of physical development (see E. G. Tanner, 1951; Goldstein, 1976), and amongst psychologists concerned with the study of learning curves (Sidman, 1952; Hayes, 1953; Estes, 1956; Tucker, 1966). However, in the study of behavioural development, in the words of Wohlwill (1973), "with only a few exceptions, work on stability, as already pointed out, has consisted in the endless proliferation of correlation coefficients, to indicate the degree of relationship between measures of behaviour obtained over some given time interval" (p. 358). Wohlwill might also have referred to measures of change in scores, which have been used by a number of workers concerned with the stability of IQs (Hildreth, 1926; Honzik *et al.*, 1948; Pinneau, 1961; Hindley & Owen, 1978). Both of these methods have the advantage over simple averaging that they take account of the relationship between measures on an individual at two points in time: either by covariation, in the case of correlations; or by subtraction in the case of difference scores. However, neither method brings to light the general course of a developmental function over time, nor the courses following by different individuals in relation to a general function, between the times of measurement (see Wohlwill, 1973).

As regards the study of individuals' curves of IQ scores over a succession of ages, Honzik *et al.* (1948) and Bayley (1956) presented examples in an illustrative way. Bayley (1949) also derived "lability coefficients" for individual children from the SD of their scores around their own means. Hilden (1949) published individual curves of 30 high IQ subjects over varying intervals from 3 to 22 years. Sontag *et al.* (1958) published curves, roughly in rank order of ascending or descending trends, for all subjects in their investigation. They identified several of the phenomena with which we are concerned, noting "consistent and extensive changes", "non-linear patterns", "irregularity of the patterns of change" (pp. 22-23), and scatter around individuals' smoothed curves (p. 30), but made no systematic analysis of the individual curves. More recently there has been some revival of interest in rates of development of measured intelligence. Thus, Jensen (1969) suggested that there are "genetic factors involved in the growth rate of intelligence", and examination of the degree of similarity of patterns of fluctuations in DQ and IQ scores has resulted in the controversy between McCall (1970; McCall & Appelbaum, 1973; McCall *et*

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89

al., 1973) and Wilson (1972, 1973; Wilson & Harping, 1972). The emphasis in these studies has been on differences in curves, rather than on the nature of the curves themselves. Up to now the McCall *et al.* (1973) study has gone farthest in classifying IQ curves, but by clustering component scores rather than by the present procedure of subjecting each individual curve to analysis.

The failure, apart from the McCall *et al.* (1973) study, to investigate patterns of change in scores over time in a systematic way, perhaps owes something to the old notion of the constancy of the IQ, with the accompanying tendency to view any changes in score as an expression of error. That such changes are often substantial has long been clear from such findings as those of Honzik *et al.* (1948) and Pinneau (1961), and has been borne out for the present sample (Hindley & Owen, 1978).

The present approach

The essence of the present approach is to examine the extent to which there is evidence of non-random, or systematic, changes in scores. Its main features may be summarized as follows:

1. The units of sampling are individual subjects, each with a series of measurements which are not independent of each other, and which can best be studied in the form of curves.
2. It is our contention that an examination of the nature of individuals' curves is logically prior to any attempt to combine them.
3. The shape of each individual's curve is characterized in terms of appropriate mathematical parameters and in terms of qualitative "by eye" judgements. Both methods are descriptive, and both permit frequency counts of similar curves.
4. For the sample of curves, estimates are made of the proportions of variance attributable to: mean amplitude; systematic trends; and residual error.
5. Any statistical treatment involving grouping of longitudinal data must be such as to take account of the characteristics or the individual curves.

This study follows a previous one in which individual and group differences in linear slopes of standardized DQ and IQ scores from 6 months to 5 years were reported (Hindley, 1962). It constitutes an extension both in the age span covered, and in the complexity of curves fitted, and is supplemented by a qualitative classification of the curves.

An important difference from the situation faced in the study of such physical growth curves as height must be emphasized. In that case the use of an objective measuring scale makes it meaningful to seek a set of mathematical parameters in terms of which any individual growth curve can be expressed, and which would equally well apply to mean growth curves (Tanner, 1951; Rao, 1958, 1965; Goldstein, 1976). Given the lack of any objective scale with equal and unchanging units in the measurement of intelligence, the shape of the mean curve of scores against age is arbitrary. If the IQ is used, it will be a horizontal straight line (by definition); if MA is used it will be a straight line at 45°; and if some such derivative as Thurstone's (1925) "absolute scaling" technique is used, it will follow a parabola. As fewer assumptions are involved in using IQs, which currently are no more than standardized deviation scores, and as they are familiar, we chose to employ them here.

Curves of individual subjects' IQ scores accordingly express their deviations from the common trend *whatever that may be*, though here arbitrarily represented as horizontal. Thus, it could only be expected that all subjects' curves could adequately be expressed in terms of similar parameters if all the curves, within chance limits, were horizontal, and therefore of zero slope. For this reason, and because—in any case—as Wohlwill (1973) points out, any fitted curve is only descriptive, there was every reason for using the simplest type of equations, namely polynomials.

Curve-fitting serves two purposes. Firstly, any individual curve for which a suitable polynomial fit yields a significant error reduction must be regarded as not following a horizontal trend, and if such fits apply to a larger number of individual curves than on chance expectation, then the null hypothesis of constancy of the IQ must be rejected for the sample as a whole. Furthermore, to the extent that different subjects' curves require polynomials of different degrees to adequately represent them, it may be concluded that they differ in shape. They may therefore be compared, both in terms of the values of the polynomial coefficients, and in terms of the degree of polynomial which yields significant improvement.

The extent to which the fitted curves serve to represent the raw curves, and therefore lead to significant error reduction, as compared with the variance of individuals' scores around their own means, can be estimated by analysis of variance techniques. Further, the relative amounts of variance attributable to the mean amplitude of individuals' curves, and to differences in components of the slopes, can also be estimated. Finally, the efficiency of a "by eye" classification of the curves can be determined in terms of the same parameters.

Some of the inherent limitations of employing IQs as the variate must be acknowledged. Wohlwill (1973) calls attention to the fact that the trend in the underlying developmental function is not known, and that there could well be changes with age in variances of measures of it. Additionally, the results would be different if a logarithmic time-scale, which has some plausibility for developmental functions (Hindley *et al.*, 1966) were employed. A rather more serious objection often raised against employing IQs is the obvious one that the nature of the variable changes qualitatively with age. As has been argued elsewhere (Hindley, 1972), the same applies to such commonly used measures of physical growth as those of height or weight, given the major changes in body proportions which occur during development, but these have nevertheless proved to be indispensable. As Urbach (1974) points out, great advances have been made in ther-

modynamics with the use of relatively crude thermometers, none of which are perfect even today. Measures of general intelligence, or of more specific abilities, are admittedly relatively crude, but they have nevertheless enabled a considerable extension of knowledge to be made. The present data are therefore offered as a contribution to empirical knowledge of patterns of development in measured intelligence, obtained from the application of commonly used tests.

Method

Subjects

Subjects were drawn from the London longitudinal study of normal development, which began in 1949 with a sample of children of widely differing social class background, recruited from a small number of antenatal clinics in central London (see Moore *et al.*, 1954).

The subjects were tested with the Griffiths Scale of Infant Development (Griffiths, 1954) at 6 months and 18 months; with the complete Stanford-Binet Form L (Terman & Merrill, 1937) at 3 years and 5 years; with starred items of the Stanford-Binet Form L (Terman & Merrill, 1960) a 8 years and 11 years; and with the AH4, a group test with verbal and non-verbal subscales (Heim, 1970) at 14 years and 17 years. The Stanford-Binet was not used beyond 11 years, because some subjects were already near its ceiling at 11 years. The AH4 was administered individually.

The criterion for inclusion in the present study was that a subject was validly tested at all, or all but one, of the ages in question, with the missing value not at the first or last age. Two overlapping longitudinal samples were selected: Sample A, 6 months-14 years, with seven assessments (n = 109; 59 boys, 50 girls); Sample B, 6 months-17 years, with eight assessments (N = 84; 47 boys, 37 girls). The mean DQs are 109 at 6 months and 104 at 18 months. Mean IQs on the Stanford-Binet are above 100, as is common in British samples, and rises from 113 at 3 years to 122 at 11 years.

To make the scores at the different ages directly comparable, the obtained scores were converted into standard scores at each age separately, with mean = 0 and SD = 1 (one unit of standard score being approximately equivalent to 20 points of Stanford-Binet IQ and 11 points of Griffiths DQ). Missing values were interpolated by taking the mean of the adjacent standard scores. (For fuller details of the testing, samples, and standardization see Hindley & Owen, 1978).

Curve-fitting

To each subject's array of scores a polynomial regression was fitted of the form:

$$y_x = a + bx + cx^2 + dx^3 + ex^4 + \ldots,$$

where y_x is the subject's score at age x (see e.g. Armitage, 1971). These polynomial equations are convenient in that the coefficients have a meaning in terms of the subject's IQ curve over time: thus a is the subject's average score, indicating the overall level; b is the coefficient of linear trend and indicates the steepness of its rise or fall; c is the coefficient of a simple curvilinear trend; d, e, etc., are coefficients of increasingly complex curvilinear trends. To fit each subject's data points exactly, the regression equation would require as many coefficients as original scores. However, typically, only the first few terms are considered, as these are the most meaningful in terms of the shape of the curve, and as they jointly tend to account for most of the variance in scores (see below). Thus, each subject's array of scores is represented by a smaller set of coefficients, each of which gives information about the shape of his curve, and the curves of different subjects can be compared in terms of the coefficients.

Starting with the linear term, successively higher degrees of polynomial were fitted. The statistical significance of any degree of curve for an individual subject is readily tested by analysis of variance (e.g. Armitage, 1971), as any obtained score y_x can be regarded as the sum of a score predicted by the regression equation of that degree, y'_x and a deviation from the regression, d_{yx}. Thus the variance of the subject's observed scores around his own mean score can be partitioned into a fraction attributable to the fitted curve, i.e. regression variance, and a residual variance about the curve, according to the equation:

$$\Sigma y_x^2 = \Sigma y_x'^2 + \Sigma d_{yx}^2$$

An F test of the ratio of the two mean squares (regression and residual) indicates the significance of the curve. Similarly the improvement in fit obtained by fitting an additional term is tested by the ratio of the increase in regression sum of squares to the new residual mean square.

For the sample as a whole, the general reduction in error variance resulting from individual curve-fitting can be seen by accumulating across all individuals, for each degree of polynomial: the regression sums of squares; the residual sums of squares; and their respective degrees of freedom. These summed values can be used to form F ratios to test the overall improvement for each degree of fit, just as for individuals. This procedure was terminated when no further significant improvement of fit occurred, and only terms up to this degree were considered in subsequent comparisons.

Partitioning of variance of curves

The total variance in scores, of all subjects over all ages, can be partitioned into a between subjects fraction, which indicates how much of the total is attributable to the difference in mean amplitude of subjects' curves (or differences in a values of the polynomial equations), and a within subjects fraction, attributable to changes in subjects' scores over time, which consists of the variance accounted for by the fitted coefficients of the polynomial (regression variance), plus residual error. The proportion of variance ac-

counted for by between-subjects variation can be estimated as a component of variance in a random effects model, in which subjects are regarded as "treatments", according to the formula (see Hays, 1973, pp. 533-534):

$$\frac{\text{MS between subjects} - \text{MS within subjects}}{\text{MS between subjects} + (k-1)\,\text{MS within subjects}}$$

where k, here, is the number of observations per subject. The remainder constitutes an estimate of the proportion of within-subjects variance.

The latter can itself be partitioned into components attributable to the successive fitted terms of the polynomial. The proportion for each component is simply the ratio of the SS due to the improvement for that term to the total within-subjects SS (Kerlinger & Pedhazur, 1973, pp. 161, 177): to express this ratio as a proportion of *total* variance, it is multiplied by the proportion of total variance attributable to within-subjects variation, indicated above. The sum of these proportions gives the total proportion of variance attributable to regression, and the remaining fraction of within-subjects variation gives the proportion of residual variance around fitted curves.

Visual classification of curves

Graphs of standard score against age were plotted by a computer for each subject in sample B, one for the whole period from 6 months to 17 years, and the other from 3 to 17 years. The shorter period was examined separately to eliminate scores based on infancy tests, which have lower correlations with scores at other ages. The curves from 6 months to 17 years were examined by the two investigators, to see whether they could be satisfactorily classified into a limited number of categories. Following a number of attempts, the following seven categories were agreed upon: (i) *up*; (ii) *up with hump*; (iii) *hump*; (iv) *down*; (v) *down with* U; (vi) U; and (vii) *horizontal*, or no definite trend (Fig. 1). The curves were independently classified by the two investigators, resulting in 53 agreements out of 84 curves for the 6 months to 17 year period, and 72 out of 84 for the 3 to 17 year period. In the discussion of disagreements it became apparent that some objective criteria were required, and with the aid of these agreement was reached. The easiest categories to distinguish were *hump* and *up with hump*, and their converses U and *down with* U. To qualify for the *hump* category a curve had to rise by more than 0.5 units, with at least two data points involved in the rise, and then to fall back near to

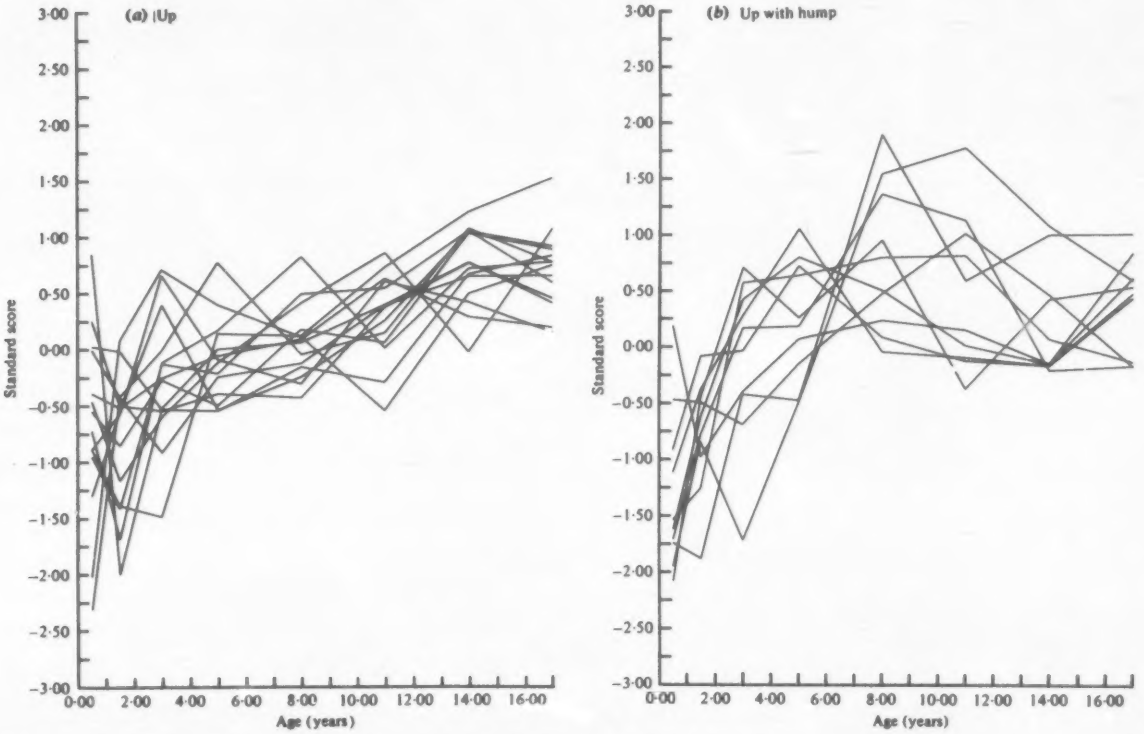

Fig. 1. Curves of standard scores of visually classified groups. *(a)-(g)* Individual curves (deviations from each individual's mean); *(h)* mean curves of each group. *(a)* Up; *(b)* Up with hump.

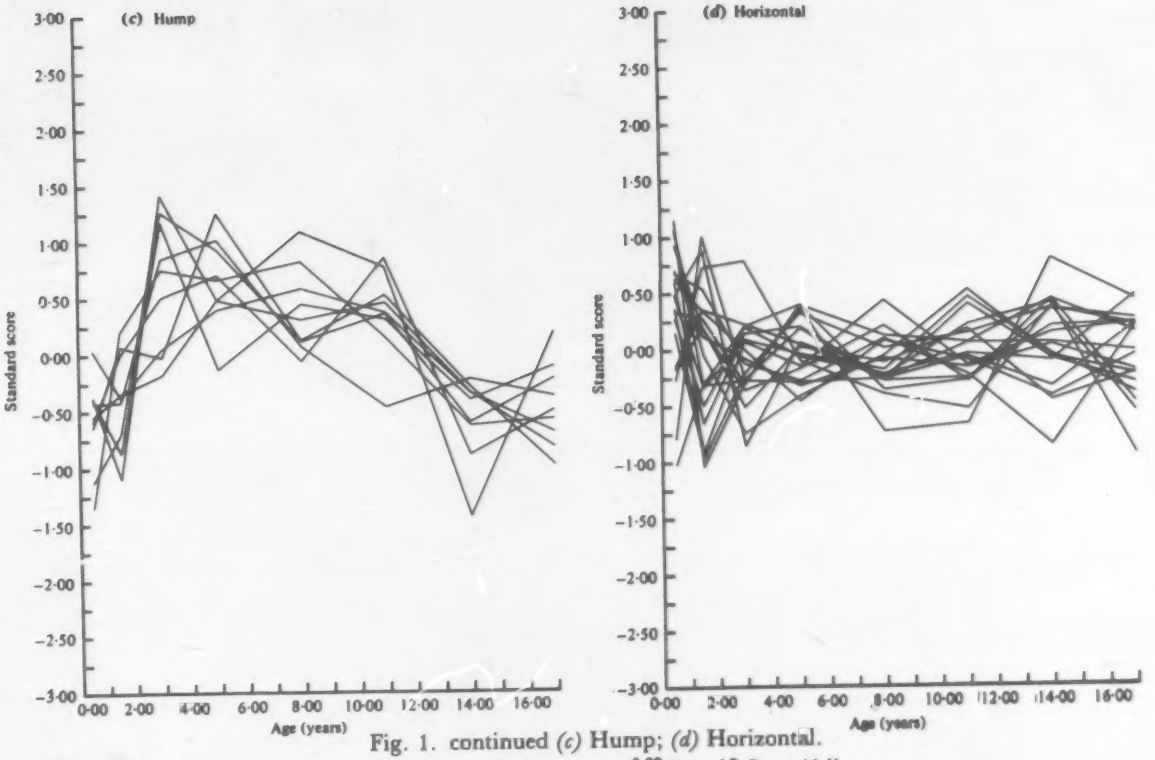

Fig. 1. continued *(c)* Hump; *(d)* Horizontal.

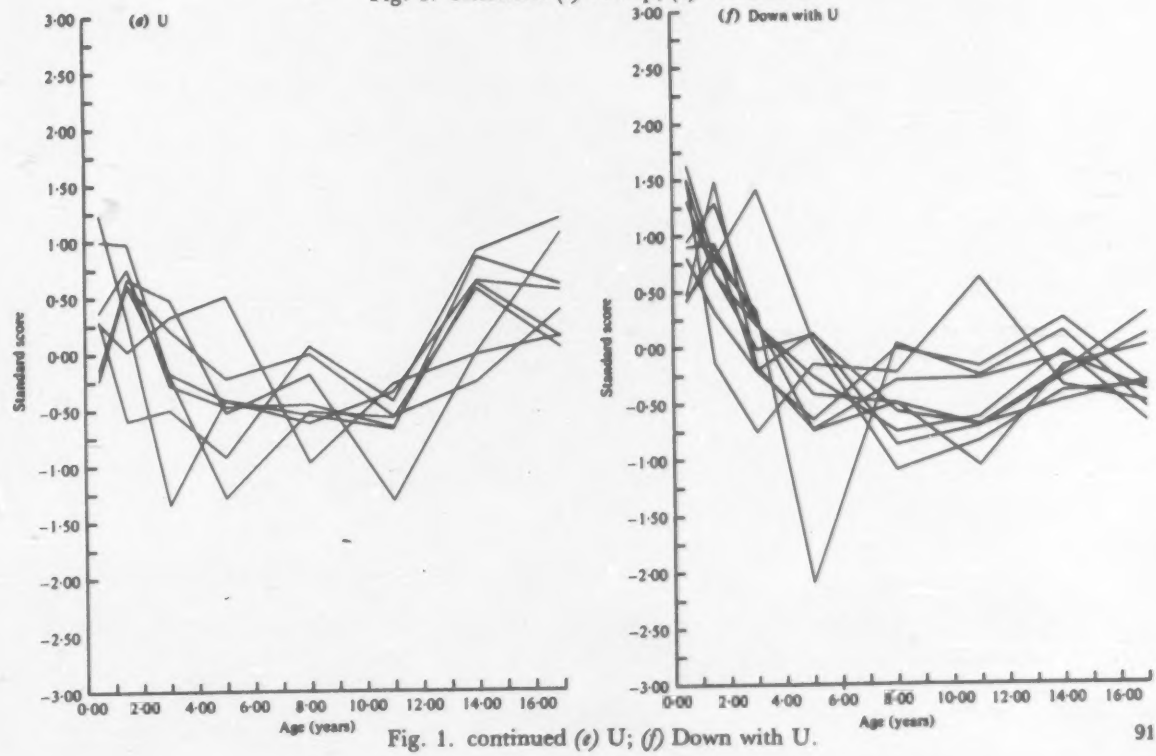

Fig. 1. continued *(e)* U; *(f)* Down with U.

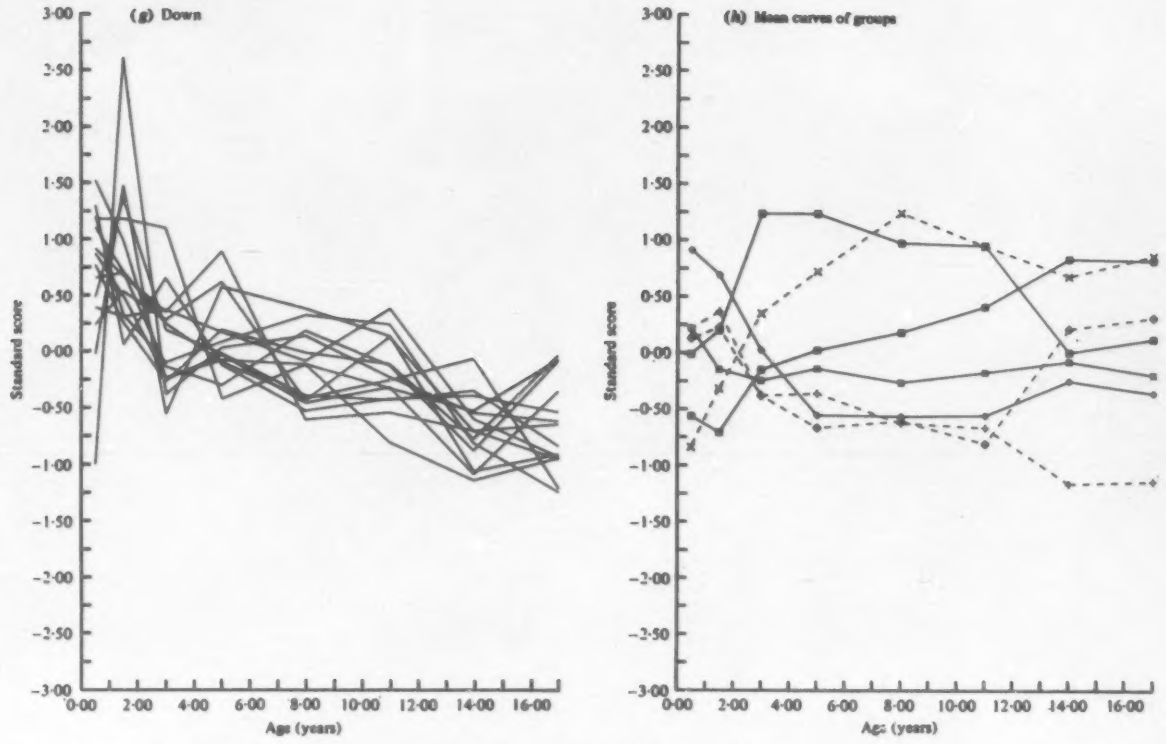

Fig. 1. continued *(g)* Down; *(h)* Mean curves of groups.

the original level, again with at least two points involved. Thus, a single high value would not count as a *hump*, nor would an otherwise *down* trend with a single low first value, nor an *up* trend with just a low final value. If an otherwise *hump* curve did not fall back to the original level, this was classified as *up with hump*. Inverse criteria applied to U and *down with* U. To distinguish the remaining curves, a criterion of a linear slope *(b)* within ± 0.045 units to qualify as *horizontal* was found to correspond well to prior judgements. The remaining curves were classified as *up* or *down*.

Comparison of grouped curves

To test the efficiency of the classification, in terms of how markedly the seven groups of curves differed, the polynomial equation of each group was contrasted with those of the other groups. For this purpose orthogonal polynomials were fitted (Finn, 1969), taking account of the unequal age intervals, and differences between the groups were analysed by a multivariate analysis of variance, using the program MULTIVARIANCE (Finn, 1972). This analysis makes a single between-groups comparison for a set of dependent variables, thus indicating whether the *sets* of polynomial coefficients of the several groups differ. This method was chosen in preference to the more usual univariate trend analysis, because in studies of growth and development the errors are likely to be correlated in ways which violate the assumptions underlying univariate analysis of variance (see Bock, 1963). However, if the multivariate test shows significant differences, step-down analyses of the different trend components will indicate the respects in which the groups of curves differ (Roy, 1958). This method is discussed fully by Finn (1969).

In addition to testing whether the grouped curves differ, it is possible to examine the extent to which the classification accounts for the fractions of the total variance already partitioned in connection with the polynomial curve-fitting. This involves a fixed effects model (Hays, 1973, pp. 484-488), concerning which there is some controversy, as compared with the random effects model, so that the estimates should be treated more tentatively. The variance accounted for by the different terms of the polynomial is subdivided into variance accounted for by the classification of curves, and a proportion not accounted for in this way, being due to variation between subjects within groups. For any component of the polynomial, the proportion due to group membership may be estimated by w^2 where

$$w^2 = \frac{[(v_2 - 2)F - 1]/v_2}{(v_2 + 1)/v_1 + [(v_2 - 2)F]/v_2}$$

Hays, 1973, p. 486), and where v_1, v_2 are the between and within groups d.f.s. They, and F, come from the analysis of variance for the appropriate polynomial component. To express these proportions as proportions of total variance, each w^2 is multiplied by the proportion of variance accounted for by the term being considered.

Results

Many of the findings are shown both for the larger sample A covering 6 months to 14 years, and the smaller sample B covering 6 months to 17 years. Greater weight should be attached to figures based on the larger sample over age intervals to which they apply. At the same time the degree of similarity of findings from the longer term, but smaller, sample, can be seen.

Correlations between scores at adjacent ages

The correlations in Table 1 show the extent to which the test results at adjacent ages have something in common, and, by correcting for attenuation (McNemar, 1969, p. 171), to what extent this is true for the underlying variables (for correlations between all pairs of ages see Hindley & Owen, 1978). While all correlations are significantly positive, it is clear that common variance between the pairs of adjacent ages up to 3 years is well below 50 per cent for the obtained scores, especially for boys, and only in one instance above that when corrected. From 3 years onwards, for girls, all correlations between scores indicate well over 50 per cent of variance in common across adjacent ages, and around 70 per cent or more between underlying variables. The boys' correlations are slightly lower, particularly between 11 and 14 years, involving two different tests. Thus, up to 3 years it must be concluded either that the tests are only to a limited degree measuring related dimensions at adjacent ages, or that subjects' scores on similar dimensions are very labile, or both.

Table 1. Correlations between scores at adjacent ages, obtained and corrected for attenuation *, for boys, girls and total sample (Gr = Griffiths scores, SB = Stanford-Binet scores, AH = AH4 scores).

	Sample A (n = 109)						Sample B (n = 84)
Age 1 Age 2	6 m (Gr) 18 m (Gr)	18 m (Gr) 3 yr (SB)	3 yr (SB) 5 yr (SB)	5 yr (SB) 8 yr (SB)	8 yr (SB) 11 yr (SB)	11 yr (SB) 14 yr (AH)	14 yr (AH) 17 yr (AH)
Boys	0.33†	0.48	0.76	0.73	0.89	0.58	0.83
Corrected	0.41	0.56	0.83	0.80	0.98	0.63	0.90
Girls	0.66	0.62	0.82	0.79	0.88	0.77	0.88
Corrected	0.83	0.72	0.90	0.87	0.97	0.84	0.96
Total	0.48	0.55	0.78	0.76	0.89	0.69	0.87
Corrected	0.60	0.64	0.85	0.84	0.99	0.76	0.95

All uncorrected correlations are significant at $P < 0.001$, except where marked † when $P < 0.01$.
* Reliabilities used to make correction:

6 m	18 m	3 yr	5 yr	8 yr	11 yr	14 yr	17 yr
0.80	0.80	0.916	0.915	0.911	0.911	0.919	0.919

Overall effectiveness of individual curve-fitting

The sums of squares due to regression, and residual sums of squares about regression, for each subject, were accumulated across individuals for each degree of polynomial. It can be seen (Table 2) that for sample B the linear fit is highly significant for each of the periods 6 months-17 years, 3 years-17 years, and 3 years-11 years. As more data points are considered, that is, as more ages are included, the number of terms yielding a significant improvement increases. Thus, from 3 to 11 years only the linear term is significant; from 3 to 17 years the quadratic term yields further improvement; and from 6 months to 17 years the cubic term yields still further improvement. In no instance did the quartic term account for significant variance. Looked at in terms of error variance, it can be seen for 6 months-17 years that the within individual variance (σ^2) amounts to 0.50, whereas that around the fitted curve is only 0.25 (SE^2_{est}); for 3-17 years equivalent figures are 0.31 and 0.18; and for 3-11 years, 0.26 and 0.19. For sample A, only the linear and quadratic components were significant.

Table 2. Error reduction for the sample as a whole from fitting successive terms to individuals' scores: Analyses of variance over different age spans (for sample B, $n = 84$).

Source	Sums of squares	d.f.	Mean square	*F*	*P*
6 m-17 yr					
Regression (linear)	107.3	84	1.28	3.41	***
Residual	188.7	504	0.37	—	—
Quadratic improvement	63.8	84	0.76	2.56	***
Regression (quadratic)	171.2	168	1.02	3.32	***
Residual	124.9	420	0.30	—	—
Cubic improvement	40.0	84	0.48	1.89	***
Regression (cubic)	211.2	252	0.84	3.12	***
Residual	84.9	336	0.25	—	—
Quartic improvement	24.1	84	0.29	1.19	n.s.
Residual	60.8	252	0.24	—	—
Total (within individuals)	296.1	588	0.50	—	—
3 yr-17 yr					
Regression (linear)	54.9	84	0.65	3.00	***
Residual	73.2	336	0.22	—	—
Quadratic improvement	28.9	84	0.34	1.96	***
Regression (quadratic)	83.8	168	0.50	2.84	***
Residual	44.3	252	0.18	—	—
Cubic improvement	15.2	84	0.18	1.04	n.s.
Residual	29.1	168	0.17	—	—
Total (within individuals)	128.1	420	0.31	—	—
3 yr-11 yr					
Regression (linear)	37.7	84	0.45	2.77	***
Residual	27.2	168	0.16	—	—
Quadratic improvement	10.9	84	0.13	0.67	n.s.
Residual	16.3	84	0.19	—	—
Total (within individuals)	64.9	252	0.26	—	—

Table 3. Number of cases with significant reduction in error variance for successive components of the polynomial up to the third degree ($P < 0.05$) (L = linear; Q = quadratic; C = cubic).

	L only	Q only	C only	L + Q	L + C	Q + C	L + Q + C	Total *n*	Sig. %	*n*
Sample A										
6 m-14 yr	27	17	9	1	1	3	1	59	54	109
3 yr-14 yr	13	11	3	1	1	1	0	30	28	109
3 yr-11 yr	13	7	—	0	—	—	—	20	18	109
Sample B										
6 m-17 yr	17	10	7	2	1	1	1	39	46	84
3 yr-17 yr	18	7	5	0	0	1	0	31	37	84

Two conclusions may be drawn. Firstly, considering the sample as a whole, the significance of the linear term for all three age periods indicates systematic upward or downward trends of individuals' scores, so that the null hypothesis of constancy of the IQ must be rejected ($P < 0.001$). Secondly, except for the shortest period, it must be concluded that curvilinear fits are required to summarize adequately the individuals' curves.

Individual differences in fitted curves

Having established that the fitting of polynomial curves up to the third degree, to each subject's series of scores, accounts for significant amounts of variance over the sample as a whole, the results of fitting a third-degree polynomial to each individual's curve can now be examined from the standpoint of differences in shape between their curves (Table 3). For each age period

considered, consistent with the above results, the number of subjects showing a significant fit at the 0.05 level, and therefore systematic trends, is far beyond the chance expectation of 5 per cent. Such trends in individuals' curves could be expected to be revealed more readily when more ages are included, and in fact for both samples the number of significant fits is greater over the longer periods, amounting to 54 per cent for the larger sample A over 6 months-14 years, and 48 per cent for the smaller sample B over 6 months-17 years. For the shorter periods of 3 years-14 years for sample A, and 3 years-17 years for sample B, 27.5 per cent and 37 per cent have significant fits. Even over the shortest period of 3 years-11 years, when only the Stanford-Binet was employed, 18 per cent have a significant fit (only linear and quadratic fits were attempted over this interval). Thus, over all the periods in Table 3, well over the chance level of 5 per cent of subjects' curves are not adequately represented by a horizontal trend, which the notion of constancy of the IQ would require, and this applies to about 50 per cent over the longer period.

Table 4. Median residual variance about fitted curves for subjects with or without significant fits ($P < 0.05$) for three polynomial terms (Sample B, 6 m-17 yr, $n = 84$).

	Any linear		Any quadratic		Any cubic	
Fitted curve	Residual variance	n	Residual variance	n	Residual variance	n
Significant fit	0.207	21	0.144	14	0.045	10
No significant fit	0.338	63	0.223	70	0.201	74

As regards the shapes of the fitted curves, linear trends—indicating a progressive upward or downward direction of scores relative to the sample—are the most frequently significant, and somewhat more commonly so over longer intervals. At the same time, substantial numbers of curves over the longer periods yielded a significant quadratic fit—denoting simple curvilinearity, and rather fewer a significant cubic fit—denoting curvilinearity with two inflections. A smaller number of curves had significant fits of two or more terms of the polynomial. Over shorter periods there tend to be fewer significant fits of higher degree terms, consistently with the smaller number of data points. From the different degrees of polynomial which yield significant fits to different subjects' arrays of scores, we may conclude that the curves which differ significantly from the horizontal also do so in a variety of ways.

Curves for which there is no significant fit merit some further consideration. The ratio of variance attributable to the fitted curve (or regression variance) to residual variance must be high to produce a significant F. This can occur even with a relatively low regression variance, as, for example, with a gentle upward linear trend, provided the residual variance is small. If the residual variance is high, a greater regression variance will be required to obtain a significant fit. Absence of significant fit can arise from curves which closely follow the horizontal throughout, so that regression variance is close to zero, and the residual variance is small. It can also occur when the regression variance is high, but the residual variance is also high, indicating that there are wide fluctuations in score around any of the three degrees of fitted curve. That some of the curves with no fit are of this type is clear from Table 4, in which it can be seen that the residual variance around each degree of curve is smaller for curves with a significant fit than for the rest.

The position is further clarified as regards the significance of the linear component in Table 5. It can be seen that for 6 months-17 years no slopes less than ± 0.05 units are significant (Table 5*b*), but for steeper slopes the proportion of significant ones is much higher when SE_{est} is small than when it is greater. Only in two instances, of marked slope, is significance accompanied by a high SE_{est}. In order to develop some criterion for distinguishing the "true" horizontal curves from markedly oscillating ones, it seems reasonable to suppose that the proportion of small slope (less than ± 0.05) curves which are "truly" horizontal is roughly the same as the proportion of larger slope curves which have linear trends significantly different from the horizontal, for each level of residual variance. On this basis the proportions of significant fit among slopes above ± 0.05 (Table 5*b*) for each level of SE_{est}, were applied to the numbers of slopes below ± 0.05 for each level of SE_{est} in Table 5*a*. The resulting numbers from the application of this admittedly crude criterion are indicated in parentheses (Table 5*b*). On this basis, the 45 curves without a significant fit over 6 months-17 years (Table 3) would be divided into 21 "truly" horizontal and 24 with fluctuating but irregular trends.

Partitioning of variance of curves

The curve-fitting results up to this point have been concerned with attempting to express the variation of subjects' scores around their own mean score, in terms of components of the polynomial, and have ig-

Table 5. Relationship between degree of linear slope and residual error (SE_{est}) *(a)* for all cases; *(b)* for those with significant linear fit (for bracketed numbers in *b* see text) (Sample B, 6 m-17 yr).

(a)

SE_{est}	−0.20	−0.15	−0.10	−0.05	Slope 0	+0.05	+0.10	+0.15	+0.20	Total	Total > ±0.05
< 0.3	—	—	1	2		1	1	1	—	6	3
0.3-0.5	1	3	6	12		5	3	3	1	34	17
0.5-0.7	—	1	4	7		5	3	1	—	21	9
0.7-0.9	—	—	2	6		3	3	1	1	16	7
0.9-1.1	—	—	1	—		1	3	—	1	6	5
1.1-1.3	—	—	1	—		—	—	—	—	1	1
Total	1	4	15	27		15	13	6	3	84	42

(b)

									Total	Proportion of all > ± 0.05
< 0.3	—	—	1	(2)	(1)	1	1	—	3	1.00
0.3-0.5	1	3	4	(9)	(4)	1	3	1	13	0.76
0.5-0.7	—	1	1	(2)	(2)	—	1	—	3	0.33
0.7-0.9	—	—	—	(1)	(0)	—	—	1	1	0.14
0.9-1.1	—	—	—	(Total 21)		—	—	1	1	0.20
1.1-1.3	—	—	—			—	—	—	0	0
Total	1	4	6	0	0	2	5	3	21	

Table 6. Estimated proportions of total variance: Between and within subjects, and components of regression (decimal points omitted).

	Sample A			Sample B		
	6 m-14 yr	3 yr-14 yr	3 yr-11 yr	6 m-17 yr	3 yr-17 yr	3 yr-11 yr
Between subjects	47	69	74	49	69	74
Within subjects	53	31	26	51	31	26
Regression	40	23	15	36	20	15
Linear	20	14	15	18	13	15
Quadratic	13	09	—	11	07	—
Cubic	07	—	—	07	—	—
Residual	13	08	11	15	11	11

nored differences between subjects' means. This is taken into account in the partitioning of the total variance (Table 6). Over the longer periods, for both samples, around 50 per cent of the total variation in scores is accounted for by differences between subjects' means, and 50 per cent by within-subject variation. Over the period 3-17 years, which omits the more unstable infance scores, the within-subjects' proportion falls to 31 per cent in both samples, and the between-subjects proportion correspondingly rises to 69 per cent. For the period 3-11 years, on the Stanford-Binet alone, the figures are 26 per cent within and 74 per cent between. Looking further at within-subjects variance, it can be seen (Table 6) that variance attributable to systematic regression falls from 40 per cent of total variance over 6 months-14 years, to 15 per cent over the shortest period, 3-11 years. However, as a proportion of within-subject variance, the fitted curves (regression variance) account for substantial proportions, ranging from 75 per cent (of 53 per cent) to 58 per cent (of 26 per cent), respectively. Over all periods, residual error variance accounts for considerably smaller proportions, whether in relation to the total variance (8-15 per cent), or to the within-subjects variance (25-42 per cent). Considering different components of regression, the linear term accounts for at least half of the regression variance over all periods, and for higher proportions over shorter periods. Conversely, the proportions accounted for by the quadratic and cubic terms diminish for the shorter periods.

Results of visual classification of curves

The foregoing objective curve-fitting methods establish that a general assumption of horizontality of individual curves, over any of the periods in question, is untenable, and that different individuals require different shapes of curves to summarize the trends of their scores over time. Visual classification of the curves, therefore, is not simply a matter of attempting to create order out of unsystematic or random variation. Furthermore, the curve-fitting results can be employed to test the efficiency of the visual classification.

It can be seen (Table 7) that substantial numbers of subjects of sample B were classified into each category, especially over the 6 months-17 years period. It is something of a coincidence that the number of horizontal curves, 19, is very near to the figure of 21 "true" horizontal curves estimated in the previous section. However, little can be made of this, as the visual method included in the horizontal category curves with wide fluctuations, which would have been excluded from the "true" horizontals. Again, instances of non-significant linear trends are sometimes classified into the *up* or *down* category. No simple correspondence of the results of the two methods can therefore be expected. Not surprisingly, over the shorter period more subjects were classified into the linear categories of *down*, *horizontal*, and *up*. This is consistent with the smaller number of significant quadratic and cubic fits (Table 3).

The effectiveness of the classifications can be judged qualitatively in Figs. 1*(a)-(g)*, which show each individual's curve plotted around its own mean, so that individual differences in amplitude are ignored. Mean curves for subjects in each of the seven categories (Fig. 1*h*) show some differences in amplitude as well as in shape.

Over the period 6 months-17 years, analysis of variance shows significant differences in amplitude of the seven groups, and multivariate analysis of variance shows highly significant differences between the group curves (Table 8). The univariate step-down, or improvement, *F*s (Roy, 1958) indicate that both the linear and quadratic components, but not the cubic, contribute to this difference. For the period 3 years-17 years there is again a highly significant difference in trend involving the linear and quadratic terms.

Table 7. Frequency of different shapes of curve (sample B).

	Down	Down with U	U	Horiz.	Hump	Up with hump	Up	*n*
6 m-17 yr	14	10	8	19	9	10	14	84
3 yr-17 yr	17	3	9	29	6	4	16	84

Table 8. Analysis of variance of differences in amplitude and trend of the groups of classified curves (sample B, $n = 84$).

Period	6 m-17 yr				3 yr-17 yr			
	Mean squares				Mean squares			
Source	Hypothesis	Error	*F*	*P*	Hypothesis	Error	*F*	*P*
Amplitude	12.11	3.83	3.16	0.008	7.72	4.20	1.84	0.10
Multivariate	—	—	22.46	0.0001	—	—	41.05	0.0001
Linear	14.27	0.28	50.60	0.0001	7.66	0.12	66.00	0.0001
Quadratic	6.12	0.18	34.33	0.0001	3.11	0.13	24.42	0.0001
Cubic	0.48	0.35	1.37	0.24	—	—	—	—

The extent to which the classification accounts for different fractions of the variance partitioned in Table 8, can be seen in Table 9. That group membership accounts for relatively little of between-subjects variance is not surprising, as the classification was based on shape alone, and was not meant to account for differences in amplitude. Just under half the within-subjects variance is accounted for by group membership in both the periods. However, as this includes residual error variance, it is more to the point that the classification accounts for 61 and 75 per cent of the systematic regression variance over 6 months-17 years, and 3-17 years, respectively. More precisely, it is accounted for by just the linear and quadratic terms. Furthermore, *F* tests of differences between regressions within groups are non-significant, so there is no evidence of significant heterogeneity within groups.

Thus, the classification has produced groups which differ very significantly in trends of curves, and it accounts for the major part of the systematic regression variance.

Table 9. Estimated proportions of variance accounted for by visual classification: Between and within classified groups (decimals omitted) (Sample B, $n = 84$).

	6 m-17 yr	3 yr-17 yr		6 m-17 yr	3 yr-17 yr
Between-subjects	49	69	Between groups	06	04
			Subjects within groups	43	66
Within-subjects	51	31	Between groups	24	15
			Subjects within groups	27	16
Total regression	36	20	Between groups	22	15
			Subjects within groups	14	05
Linear	*18*	*13*	Between groups	*14*	*11*
			Subjects within groups	*04*	*02*
Quadratic	*11*	*07*	Between groups	*08*	*04*
			Subjects within groups	*03*	*03*
Cubic	*07*	—	Between groups	*00*	—
			Subjects within groups	*07*	—
Residual	15	11			

Discussion and conclusions

By the logic of curve-fitting, if the estimate of variance accounted for by the fitted curve is significantly greater than residual variance around it, the null hypothesis of absence of trend, or horizontality of the variable in question, is to be rejected, and the fitted trend can be taken as providing a better expression of the relationship between the two variables under consideration. On this basis, the null hypothesis of constancy of IQ scores over time, with or without the inclusion of DQ scores, and over all periods considered, can be rejected with a high degree of confidence for the present sample. Instead, it is to be concluded that individual IQ curves show systematic trends, rather than random variation around the horizontal. This is shown by the significant reductions in error variance when regression and residual SS are summed over the whole sample; and by the proportion of individual curves with significant fits, ranging from 18 per cent over 3-11 years on the Stanford-Binet, to 54 per cent over 6 months-14 years, when scores are on three different tests.

Furthermore, different values of polynomial coefficients, and different degrees of polynomial curve, are required to account adequately for the variance of the scores of different individuals. This indicates that individual curves of scores differ not only in slope, but also in form.

Partitioning the total variance shows that between a quarter and a half of the total variation in IQs is attributable to changes in individuals' scores over time (26 per cent over the shortest period, 3-11 years, on the Stanford-Binet alone; 53 per cent over 6 months-14 years). It also reveals that the systematic variance associated with the fitted curves is not only significant, but substantial, amounting to a minimum of 58 per cent of the within subjects variance over 3-11 years, and a maximum of 75 per cent over 6 months-14 years. The fact that the linear trend accounts for the biggest part of this, over all periods, is partly attributable to the stepwise procedure of fitting the simplest curves first. Residual unsystematic errors around the fitted curves only account for 8 to 15 per cent of the total variance, and 25 to 42 per cent of within-subjects variance.

It is noteworthy that the method of visual classification (Fig. 1) was successful in accounting for a high proportion of the systematic variation. It therefore provides an easily applicable means of analysing many kinds of developmental data, in a way which takes account of the form of individual trends. The results of applying this simple method of classification are broadly similar to those of McCall *et al.* (1973) using procedures of cluster analysis.

A concrete picture of the variety of curves is provided in Fig. 1, and Table 5 shows a distribution of linear slopes. The minimal slopes which are significant ($\pm$ 0.05 units), imply a rise or fall of 0.8 SD units over 6 months-17 years, or about 16 points of Stanford-Binet IQ in this sample. Nine out of 84 subjects have slopes implying a gain or loss of 1.65 SD units (33 IQ points). It can also be seen in Fig. 1 that subjects with curves classified as *hump* or U can gain or lose 1½ to 2 SD units (30 to 40 IQ points) and then return to the initial score level. Nor are changes of this type absent when the infancy tests are omitted from consideration.

The systematic nature of the differing trends brought to light casts doubt on the value of using a subject's standard deviation around his own mean, Bayley's (1949) "lability coefficient", as a measure of instability of scores. This will certainly permit detection of subjects with relatively stable scores, but it makes no distinction between those with steady linear, or curvilinear trends, and others displaying large, but unsystematic fluctuations. It also takes no account of the ages at which any changes occur.

As regards interpretation of the findings, there are two possible misconceptions that are worthy of comment. It might be thought that because only 18 per cent of subjects display significant trends from 3 to 11 years, scores of the rest are stable. This by no means follows. The fits for these subjects are significant when each curve is considered on its own, without using any other information. However, other evidence makes it clear that in the case of the linear trend, for example, there

is a continuous distribution of coefficients—or slopes—and that the 18 per cent of subjects are towards the extremes of it. This can be seen in Table 5, and by an examination of Fig. 1. Trend coefficients are therefore to be regarded as a variable in which there is a distribution of individual differences, similar in principle to the more familiar distribution of subjects' mean scores.

Secondly, it might be tempting to attribute variance between subjects (expressing differences in their mean scores) to hereditary factors, and within subjects variance to environmental ones. A horizontal IQ curve, however, itself specifies a particular curve on the underlying developmental function, the form of which cannot be unequivocally determined but may plausibly be roughly parabolic (Thurstone, 1925; Bayley, 1955; Bloom, 1964). A contention that departures from constancy of the IQ occurred only as a result of differential environmental influences would imply that individual developmental curves never crossed in a constant environment. This would be most unlikely as developmental curves of other parameters do, in fact, cross, for example those of weight of mice reared under standard conditions (Roberts, 1961), and in humans not only is there a genetic influence on rates of growths (Vandenberg & Falkner, 1965), but also on the timing of changes of rate, particularly as regards menarche and the adolescent growth spurt (Tanner, 1970). There is therefore every reason to expect that heredity will affect within individual variation in curves of ability as well as overall level, and some support for this is provided by Wilson (1972), at least during the first year (McCall *et al.*, 1973).

There is no doubt that IQ can change as a result of environmental changes (Clarke & Clarke, 1974), but there is also evidence that early stimulation or enrichment of the environment, in animals, can affect the entire course of physical and behavioural development (Levine & Mullins, 1968; Thompson & Grusec, 1970). As regards humans, a continuing unfavourable environment has been shown in many studies to depress the general level of IQ, from which recovery can occur when conditions are improved (e.g. Clarke & Clarke, 1954; Clarke *et al.*, 1958; Koluchova, 1972, 1976). In contrast, Heber's (Heber *et al.*, 1972; Garber & Heber, 1977) study on disadvantaged children, provides evidence that a relatively high level of IQ can be maintained with a continuing educational intervention programme. Thus environment can affect general level of scores, as well as changes in scores. How far can the present results be generalized to a wider population? There can be no denying that the sample consists of cooperative subjects, and that Census data provide no suitable breakdowns which would permit adequate social class comparisons. It nevertheless contains subjects from a wide range of social backgrounds (see Hindley & Owen, 1978). We are in no position to claim that the proportions of significant fits to terms of the polynomial, nor the proportions classified into the seven categories of the visual classification, would necessarily be found in the general population. However, if the sample is biased, this is likely to make it more, rather than less homogeneous, and this could be expected to apply to coefficients of slopes of IQ curves, as much as to any other variate. It is reasonable to suppose, therefore, that there may well be a greater amount of variation in IQ curves in the general population.

A further point which might affect generalizability is that the mean scores of the samples rise from a DQ of about 106 in infancy to an IQ of over 120 on the Stanford-Binet. This may reflect practice effects as well as possible sampling bias (see also Hindley & Owen, 1978). It is nevertheless difficult to see how they could readily be invoked to account for the large individual differences in slopes and degrees of curves. The relatively high mean scores of the sample on the Stanford-Binet are in any case likely, in part, to reflect the common finding in British samples of a mean IQ several points above 100.

If then we can take it that the present findings are likely in a broad way to be true of the population, the results have a number of important general implications. From traditional testing theory, large shifts in score can be regarded as meaningful when they are of an order well beyond the changes to be expected on the basis of short-term test-retest reliabilities. However, what emerges from the present analysis is that the single IQ score amounts to an observation at one point in time on a curve which may be horizontal, rising or falling more or less steeply, or following a curvilinear trend—a trend about the nature of which the tester is in ignorance. The fact that substantial changes of IQ can occur between two testings, as has been already reported for the present sample (Hindley & Owen, 1978) and by others, is to be regarded as in no way surprising, and as being, in large measure, the reflection of systematic change.

Similarly, the present results emphasize the need for caution in interpreting research studies which assume that an IQ score at virtually any age after infancy may be taken as being typical of the individual. The literature on hereditary and environmental factors related to IQ provides many such examples, including comparisons between siblings of different ages, and between parents and children, although the findings of Honzik (1957) and Skodak & Skeels (1949) have shown how much correlations are affected by a child's age, and recent work of Bayley (1970) and Honzik *et al.* (1976) has revealed that IQs of adults can change considerably.

It must be admitted that our data depend on the application of three particular tests, at particular ages. A pragmatic justification for the analyses we have performed is, that as these, or similar, tests are commonly used to assess children's general cognitive ability, or intelligence, the results are relevant to such use. Undoubtedly different tests, or different ages of testing, could be expected to give rise to somewhat different curves. However, because no test is in any sense perfect, it by no means follows that results based on a particular set of tests are spurious. Certainly it would be highly desirable to be able to supplement results based on predominantly verbal tests of intelligence by

equivalent data in which verbal and several non-verbal skills were separately assessed, as well as "fluid" and "crystallized" intelligence (Cattell, 1963; Horn, 1970). This must await further longitudinal studies, and the further development of suitable instruments.

Our results have important implications for developmental research. Identifying systematic trends in IQ scores is only the first step. The phenomena having been brought to light, the next step is to investigate the influence of factors which may be related to them. These will be the subject of further reports. More generally it can be expected that the application of similar methods to successive measurements of other parameters, personality traits for example, would reveal similar phenomena.

Finally, in view of the criticism sometimes levelled at longitudinal researches such as ours, on account of the relatively small size and probable bias of the samples, it is perhaps worth remarking that results of the kind reported have yet to appear from any large-scale investigation on a representative sample. Nor does there seem much likelihood that this will occur in the near future. Such information as we have on the stability and change of individuals' ability from infancy to maturity comes from this and similar small sample longitudinal studies, as for example at Fels (e.g. McCall *et al.*, 1973) and Berkeley (see Jones *et al.*, 1971) in the USA, and the group of European studies of which we are one, collaborating through the International Children's Centre (Falkner, 1960).

ACKNOWLEDGEMENTS

One of us (CBH) is especially indebted to Dr F. Yates for his seminal suggestion concerning the use of curve-fitting methods in studying IQ trends in children. We would also like to thank Mr A. Westlake for advice concerning individual curve-fitting, Dr B. Baughan in connection with multivariate methods, Professor T. Moore and Miss J. A. Munro for their help in testing and more generally, Miss S. Sharpe, and Mrs S. Clautour for help with the manuscript, and the Social Science Research Council and Institute of Education for supporting this work.

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Parent-child correlations for body measurements of children between the ages one month and seven years*

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There have been a number of studies establishing the correlation between parents and offspring for various body measurements, but for the most part these relate to measurements made on the offspring when adult. The age at which the adult parent-offspring correlation is established, and the course of its previous changes as the child grows, has only been investigated once on a very small number of persons (Bayley, 1954). Yet it is clear that an understanding of the genetics of normal quantitative characters in man will never emerge from a static analysis of their adult correlations; we need instead to consider what these correlations represent in terms of the physiological control of growth processes. A study of their development is a first step in this direction.

Being engaged in a longitudinal growth study in which so far the children have been measured at intervals from 1 month after birth to 7 years, we have been able to follow during this period the development of the resemblance of offspring to parent for a number of measurements. We hope to follow the children to adulthood and report later the changes from 7 years onwards. A short preliminary account of this work has already appeared (Tanner & Israelsohn, 1962).

MATERIAL AND METHODS

The children were those enrolled in the longitudinal study being carried out at the Child Study Centre of the Institutes of Child Health and Education of the University of London. The method of recruitment is detailed in Moore, Hindley & Falkner (1954); it is sufficient here to say that the sample is approximately a random selection of children born in the West Central area of London, made by recruiting mothers during pregnancy. Out of an original sample of 220 children, about 170 were still attending at age 7, but not every one of these had attended on each occasion. In addition there were a very few whose mothers could not be persuaded to be measured. We were finally left with a pure longitudinal series of 117 children each measured at 3, 6, 9 months, 1 year, 1½ year, 2, 3, 4, 5, 6 and 7 years. Of these 104 were measured at 1 month, so the sampling error from this age to the remainder of the series is not very great. No family was represented by more than one child.

The mothers of all these children were measured, the majority by Israelsohn, the remainder by Tanner. We had more difficulty in persuading the fathers to attend for measuring, but eventually secured 57 of them. All these were measured by Tanner. The age range of the mothers was 23 to 52 (average 37) and of the fathers 27 to 64 (average 41). No corrections have been made for age changes in stature or other measurements. The regression of stature on age in this group was -1.5 ± 1.0 cm./decade for mothers and -1.4 ± 1.2 cm./decade for fathers. The average heights were fathers 173.7 ± 0.83 cm., mothers 160.5 ± 0.55 cm. Calculation of a sample of partial correlations showed that keeping parent's age constant elevated the correlations given below by less than 0.01. The children, unfortunately, were measured by six different persons at different ages; notably Dr Frank Falkner, Miss Coral Tibbetts, Dr P. Sylvester, Mr Peter Jones and the authors.

The *anthropometric measurements* taken were supine length (stature in parents), crown-rump (sitting height in parents), weight, bi-iliac and biacromial diameters, widths across the condyles of the humerus and femur, calf circumference, head circumference, and four measurements of subcutaneous fat by skinfolds—over biceps, over triceps, under scapula and above iliac crest. These skinfold measurements were taken with the Harpenden Skinfold Caliper, transformed to logarithms after subtraction of 1.8 mm. for skin thickness (see Edwards *et al.*, 1955) and the transforms summed for each individual. Leg length was calculated as supine length less crown-rump, or stature less sitting height.

The anthropometric methods used for the children are given in detail in Falkner (1960). Methods for the adults were exactly similar, except that stature and sitting height replaced supine and crown-rump lengths. Stature was taken with the subject fully stretched upward, aided by gentle traction on the mastoid processes, with a counter-weighted, freely moving board resting lightly on his head. This eliminates, or greatly reduces, the time of day variation otherwise seen. Sitting height was taken with the subject sitting on a table with the legs hanging over the edge, the back fully straightened and stretched upwards; a Martin anthropometer was used. Weight was taken in the nude or in a standard gown, the weight of which was subtracted.

In the correlations that follow stature and sitting height are paired with supine length and crown-rump, respectively, without further comment; this reduces their correlations to a similar degree at all ages, probably by no more than 5%. In our 8-year-olds stature correlates 0.998 with supine length and sitting height

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Numbers of pairs (from 3 months onward): father-son 30; father-daughter 27; mother-son 60; mother-daughter 57. (At 1 month: 28, 25, 50 and 52, respectively.)

	Months				Years							
	1	3	6	9	1	1½	2	3	4	5	6	7
Supine length												
F-S	−0.13	0.41	0.47	0.30	0.50	0.40	0.52	0.40	0.44	0.44	0.44	0.45
F-D	0.42	0.21	0.28	0.36	0.14	0.10	0.17	0.17	0.11	0.10	0.08	0.20
M-S	0.21	0.33	0.36	0.37	0.40	0.42	0.37	0.43	0.45	0.44	0.46	0.48
M-D	0.33	0.40	0.46	0.46	0.50	0.58	0.58	0.56	0.61	0.57	0.60	0.62
Crown-rump												
F-S	−0.13	0.28	0.29	0.13	0.13	0.11	0.14	0.28	0.34	0.25	0.31	0.29
F-D	0.14	0.16	0.26	−0.03	0.08	0.07	0.24	0.22	0.13	0.19	0.17	0.26
M-S	0.17	0.09	0.20	0.14	0.21	0.18	0.20	0.27	0.32	0.32	0.30	0.30
M-D	0.15	0.39	0.52	0.45	0.46	0.50	0.55	0.46	0.50	0.57	0.62	0.52
Leg length												
F-S	0.04	0.29	0.59	0.23	0.40	0.45	0.42	0.33	0.51	0.46	0.46	0.54
F-D	0.23	−0.01	0.25	0.39	−0.09	−0.12	−0.10	−0.25	−0.16	−0.08	−0.09	0.03
M-S	0.25	0.30	0.30	0.49	0.32	0.46	0.40	0.43	0.38	0.46	0.45	0.51
M-D	0.16	0.34	0.12	0.25	0.31	0.33	0.60	0.53	0.50	0.36	0.50	0.51
Head circumference												
F-S	0.08	0.26	0.32	0.27	0.31	0.28	0.35	0.40	0.42	0.36	0.48	0.47
F-D	0.39	0.30	0.53	0.53	0.62	0.60	0.61	0.60	0.68	0.69	0.62	0.65
M-S	0.35	0.19	0.24	0.28	0.34	0.30	0.31	0.30	0.31	0.34	0.29	0.32
M-D	0.27	0.29	0.33	0.22	0.23	0.30	0.37	0.40	0.45	0.40	0.45	0.44
Biacromial												
F-S	—	—	—	—	—	—	—	—	0.50	0.42	0.48	0.52
F-D	—	—	—	—	—	—	—	—	0.01	−0.02	0.09	0.02
M-S	—	—	—	—	—	—	—	—	0.37	0.38	0.41	0.43
M-D	—	—	—	—	—	—	—	—	0.16	0.32	0.39	0.37
Bi-iliac												
F-S	0.26	0.36	0.31	0.30	0.38	0.23	0.29	0.28	0.29	0.29	0.26	0.31
F-D	0.19	0.14	0.33	0.16	0.29	0.44	0.23	0.28	0.31	0.35	0.36	0.41
M-S	0.30	0.34	0.33	0.36	0.29	0.31	0.40	0.38	0.43	0.43	0.45	0.47
M-D	0.36	0.36	0.31	0.29	0.32	0.39	0.30	0.46	0.46	0.44	0.45	0.42
Bicondylar humerus												
F-S	0.03	0.35	0.36	0.29	0.19	0.24	0.01	0.36	0.39	0.42	0.32	0.41
F-D	0.29	0.50	0.23	0.30	0.26	0.19	0.04	0.05	0.05	−0.02	0.19	0.13
M-S	0.22	0.17	0.02	0.16	0.02	0.27	0.33	0.31	0.31	0.43	0.42	0.50
M-D	0.17	0.08	0.21	0.27	0.17	0.33	0.44	0.42	0.57	0.47	0.49	0.55
Bicondylar femur												
F-S	0.19	0.23	0.47	0.29	0.26	0.28	0.28	0.29	0.35	0.41	0.36	0.39
F-D	0.17	0.16	0.10	0.04	0.09	0.13	0.16	0.12	0.20	0.21	0.20	0.16
M-S	0.21	0.20	0.16	0.28	0.24	0.43	0.40	0.50	0.44	0.48	0.47	0.48
M-D	0.08	0.26	0.21	0.39	0.17	0.34	0.48	0.51	0.53	0.55	0.52	0.52
Weight												
F-S	−0.10	0.30	0.25	0.14	0.21	0.11	0.07	0.07	0.16	0.17	0.08	0.17
F-D	0.04	0.04	0.01	0.07	0.20	0.26	0.29	0.24	0.20	0.21	0.23	0.30
M-S	0.55	0.45	0.32	0.28	0.34	0.38	0.40	0.36	0.40	0.46	0.49	0.47
M-D	0.41	0.30	0.22	0.30	0.38	0.47	0.54	0.57	0.57	0.57	0.51	0.49
Skinfolds												
F-S	—	—	—	—	—	—	—	0.02	0.03	0.10	0.00	0.15
F-D	—	—	—	—	—	—	—	0.30	0.39	0.40	0.41	0.44
M-S	—	—	—	—	—	—	—	0.08	0.10	−0.01	−0.09	−0.03
M-D	—	—	—	—	—	—	—	0.03	0.10	0.16	0.22	0.13

Table 1 (cont.)

	Months				Years							
	1	3	6	9	1	1½	2	3	4	5	6	7
Arm circumference												
F-S	—	0.22	0.22	0.05	0.05	0.22	0.28	0.21	0.29	0.33	0.17	0.28
F-D	0.01	−0.17	0.00	0.22	−0.13	0.03	0.20	0.07	0.12	0.12	0.10	0.13
M-S	−0.02	0.20	0.09	0.13	0.08	0.15	0.10	0.03	0.20	0.28	0.39	0.38
M-D	−0.02	0.12	0.24	0.20	0.10	0.24	0.33	0.42	0.43	0.35	0.27	0.25
Calf circumference												
F-S	—	0.21	0.20	0.23	0.32	0.05	0.11	0.07	0.10	0.14	0.12	0.15
F-D	0.18	0.05	0.14	0.01	0.07	0.25	0.32	0.28	0.40	0.41	0.35	0.36
M-S	—	0.17	0.13	0.03	0.02	0.11	0.09	0.18	0.28	0.30	0.42	0.42
M-D	−0.19	0.28	0.24	0.23	0.26	0.29	0.43	0.50	0.50	0.48	0.48	0.48

Table 2. Combined values of parent—offspring correlation coefficients: (F-S, F-D, M-S, M-D)

At 1 month 154 pairs of values; from 3 months onward 174 pairs, pure longitudinal. Father-mother correlation in left-hand column: 57 pairs.

F-M		Months				Years							
corr.		1	3	6	9	1	1½	2	3	4	5	6	7
0.13	Supine length	0.24	0.35	0.40	0.39	0.41	0.42	0.44	0.44	0.46	0.44	0.45	0.48
0.08	Crown-rump	0.11	0.24	0.34	0.23	0.28	0.28	0.33	0.35	0.38	0.38	0.41	0.38
0.08	Leg lenght	0.18	0.26	0.29	0.35	0.24	0.33	0.40	0.35	0.36	0.35	0.39	0.43
−0.11	Head circumference	0.28	0.25	0.33	0.31	0.35	0.35	0.40	0.41	0.44	0.44	0.44	0.45
0.11	Biacromial	—	—	—	—	—	—	—	—	0.27	0.31	0.36	0.36
0.18	Bi-iliac	0.27	0.32	0.32	0.29	0.32	0.35	0.33	0.38	0.40	0.41	0.41	0.42
0.24	Bicondylar humerus	0.19	0.23	0.17	0.24	0.14	0.29	0.28	0.32	0.38	0.38	0.40	0.46
0.20	Bicondylar femur	0.17	0.22	0.23	0.31	0.20	0.33	0.37	0.41	0.41	0.44	0.43	0.43
0.21	Weight	0.34	0.31	0.23	0.24	0.31	0.34	0.38	0.38	0.40	0.42	0.40	0.46
0.17	Skinfolds	—	—	—	—	—	—	—	0.08	0.14	0.14	0.08	0.14
0.11	Arm circumference	—	0.11	0.15	0.16	0.06	0.17	0.22	0.20	0.27	0.28	0.27	0.29
0.15	Calf circumference	—	0.20	0.19	0.13	0.16	0.18	0.25	0.29	0.35	0.36	0.39	0.40

0.985 with crown-rump; these figures should give a good approximation to the correlations obtained with our technique in adults.

The *correlations* were calculated between father-son (F-S), father-daughter (F-D), mother-son (M-S) and mother-daughter (M-D) separately at each age for each measurement. We are greatly indebted to Mr Howard Simpson of the Department of Statistics at Rothamsted Experimental Station for help with these correlations, which were done on the digital computer there. Subsequent combinations of these four values were made through conversion of the coefficients to z values, weighting by number of cases where necessary, and reconversion to r.

RESULTS

(a) Combined parent-offspring

The values of the four parent-child coefficients at each age are given in Table 1. Before examining these individually, however, it is instructive to examine the coefficients resulting from combining all the data. These are given in Table 2, together with the parent-parent correlations. These coefficients are based on 174 pairs of values from 3 months onwards, and 154 pairs of values at 1 month. It must be remembered that there were approximately twice as many mothers as fathers represented, so that if (as will subsequently appear) there are significant differences between mother-child and father-child correlations the combined correlations reflect the former values to a greater extent than the latter. The standard error of z at 171 D.F. is 0.077 which leads to 95% confidence limits of, for example, 0.33 to 0.55 for the value $r = 0.44$ (supine length at ages 2, 3 and 5). The sample is still not large enough, therefore, to locate the population figure with a great deal of accuracy. Since the series is longitudinal, however, the sampling error of the difference between any two values in the series in the tables is very much less than this, reflecting more measurement error than population

sampling. Its magnitude cannot be stated exactly, but it is certainly too small for error to account for the major features of the trend of the figures.

The chief feature of the correlation for supine length is the rise from a low level at 1 month to a relatively high one at 1 year and a still higher one at 2, after which the rise becomes very gradual. The curve is exponential in its general shape. The two components of supine length, that is, *crown-rump* and *leg length*, show similar trends though more disturbed in the first 2 years, in all probability by measuring errors during a difficult period when measurers changed too often.

The correlation for *weight*, however, shows a drop from 1 to 9 months which is probably not due to measuring error. In other respects it resembles the graph for supine length. *Calf circumference* resembles weight: we have no figures for 1 month here. *Bi-iliac diameter* resembles supine length more than weight, though it has a slight fall at 9 months. *Biacromial diameter*, measured only from 4 years onwards, parallels the others. The *skinfold thickness* correlations, however remain at a uniformly low level.

Head circumference has correlations closely resembling supine length, and the *bicondylar* widths of *humerus* and *femur* also resemble supine length, probably disturbed by a good deal of measuring error at 1 year. *Arm circumference* parallels bicondylar humerus more than any other measurement.

The explanation for the drop to 9 months in the series of weight and calf circumference (and possibly the minor ones in some other measurements) is not far to seek. The baby puts on much fat from birth to about 9 months and thereafter loses it (Tanner & Whitehouse, 1962). The amount of this infant fat may not be closely related to the amount of childhood fat put on later, and may be still less related to the parents' fat. The presence of this independent element would lower the correlations. Secondly, the tempo of this fat wave varies from one child to another, some reaching the peak of their fat at 6 months, others at 18 months. This also will lower all the correlations in the same way the child-to-adult height correlations are lowered at adolescence by the variation in time of the adolescent spurt (see Fig. 6).

(b) Father-son, etc., coefficients

Supine length. In Table 1 are shown separately the father-son, father-daughter, mother-son and mother-daughter coefficients for supine length. The mother-offspring correlations are those based on all the mothers, that is twice the number of available fathers. As it so happens the mother-offspring correlations for mothers whose husbands participated were substantially (but not significantly) below those for mothers whose husbands failed to attend.

The mother-daughter coefficients are the highest and are all above the mother-son coefficients. The differences are not significant, however, t ranging from 0.6 to 1.4 from 6 months on. (The significance test used ignored the possible covariance between the two r's and hence if anything underestimates: see McNemar, 1949, p. 124.) However, when we consider all the data in the literature, displayed in Fig. 1, there is no question that this difference is a biological one and not due to the vagaries of sampling. (The data from Bayley, 1954, are nearly pure longitudinal and number approximately 23 sons and 23 daughters; at most ages the differences in her sample reach significance. Thomson's (1955) data show a significant difference; Kagan & Moss's (1959) data are mixed longitudinal and give a t of 1.86 at age 3; Hewitt's (1957) data are pure longitudinal and have t values similar to ours.) The data are impressively consistent; Hewitt's (1957) correlations seem in general rather low, perhaps because he was operating on data which may have been collected with less regard for anthropometric accuracy than the other series. It is perhaps worth noting that after age 7, according to Bayley's data, the gap between the mother-daughter and mother-son coefficients tends to close; Kagan & Moss supply one point at age 10, which agrees with this (see Tanner, 1960, for illustration after age 7).

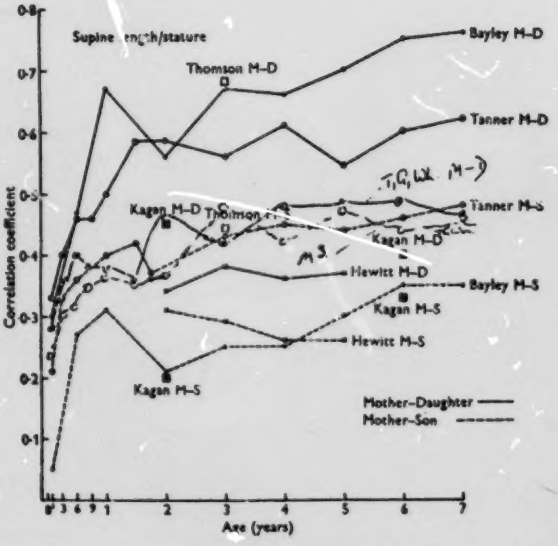

Fig. 1. Comparison of mother-son (M-S) and mother-daughter (M-D) correlations for supine length or stature in all available data. Solid lines M-D in all series; broken lines M-S. Points . – . from Bayley (1954); approximately 23 children of each sex, followed longitudinally. Points □ from Thomson (1955) 95% confidence intervals ± 0.2; × — × from Hewitt (1957) 95% confidence intervals ± 0.12; ■ from Kagan & Moss (1959) 95% confidence intervals approximately ± 0.24.

According to our data this difference in correlations for supine length comes largely from the crown-rump element rather than from leg length (see Table 2). In crown-rump the overall difference between mother-daughter and mother-son coefficients is about the same for supine length, whereas for leg length there is little consistent difference to be seen.

The father-son coefficients in our supine length data (Table 1) are consistently above the father-daughter coefficients, though not significantly so, the t values ranging up to 1.4 (at 2 years). Bayley's (1954) data give a similar result, with a few points reaching a significant difference. Kagan & Moss's (1959) data at 3 and 6 give the reverse, however, father-son being (insignificantly) less than father-daughter. It thus looks as though a similar result for fathers as for mothers (same sex higher) *may* be true, but is as yet uncertain. In distinction from the situation in mothers, our data show the father-son correlation to be chiefly, and indeed at some ages significantly, greater than father-daughter for leg length, and only very slightly so for crown-rump.

When the two mother correlations are pooled and compared with the two pooled father correlations the mothers are higher in our data and in Bayley's, though not in Kagan's. This is probably only due to the mother-daughter/mother-son difference being so relatively large. The pooled son correlations do not differ from the pooled daughter correlations in our data, though the daughters were generally higher in Bayley's material.

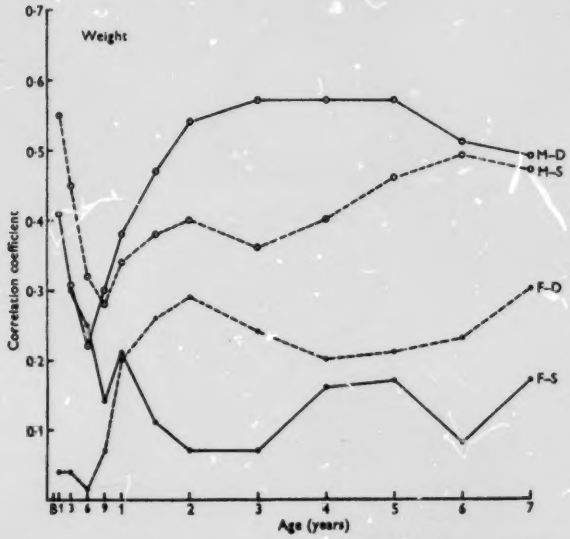

Fig. 2. Father-son (F-S), father-daughter (F-D), mother-son (M-S) and mother-daughter (M-D) correlation coefficients for weight. F-S based on 30 pairs, F-D 27, M-S 60, M-D 57.

Weight. In our data (Fig. 2) the maternal correlations for weight are at all ages above the paternal correlations. In the only other published data, those of Bayley (1954), this is true during the first year only. Both sets of data give the same high maternal correlation at one month (Bayley 0.41 and 0.37) followed by the decrease to 1 year. This result is expected since birth weight is almost entirely dependent on uterine factors and independent of the genotype of the fetus, so far as growth potential is concerned (Tanner *et al.* 1956; Penrose, 1961).

After 1 year the mother-daughter correlations are higher than the mother-son correlations, but the highest t value for their difference is 1.4; in Bayley's data, however, the mother-daughter values are very significantly above those of mother-son. In neither data is there much indication of a significant difference between father-son and father-daughter.

Other measurements. In *head circumference* (Fig. 3) the usual trend is reversed, father-daughter being consistently above father-son, with t values ranging up to 1.7. Mother-daughter is slightly higher than mother-son.

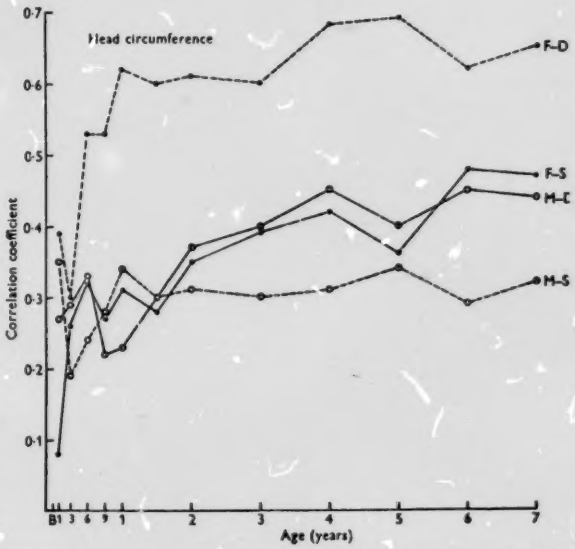

Fig. 3. Father-son (F-S), father-daughter (F-D), mother-son (M-S) and mother-daughter (M-D) correlation coefficients for head circumference. F-S based on 30 pairs, F-D 27, M-S 60, M-D 57.

In *bi-iliac diameter* (Fig. 4) all four correlations are quite close together, whereas in *biacromial diameter* (Fig. 5) there is a difference between father-son and father-daughter correlations which reaches to 5% significance level at age 4 and 7, despite the relatively small number of cases.

In *bicondylar diameters,* both of the humerus and femur, the mother-daughter correlations are only slightly higher than the mother-son correlations, and the father-son are somewhat, though not significantly, above those of father-daughter. The same holds true for arm circumference, but for calf circumference, father-daughter correlations exceed somewhat those of father-son after age 2. This parallels the situation for subcutaneous fat as measured by the skinfolds where the father-daughter correlation from 3 onwards is the only one to give any indication of being significantly above zero, with t's of around 1.4

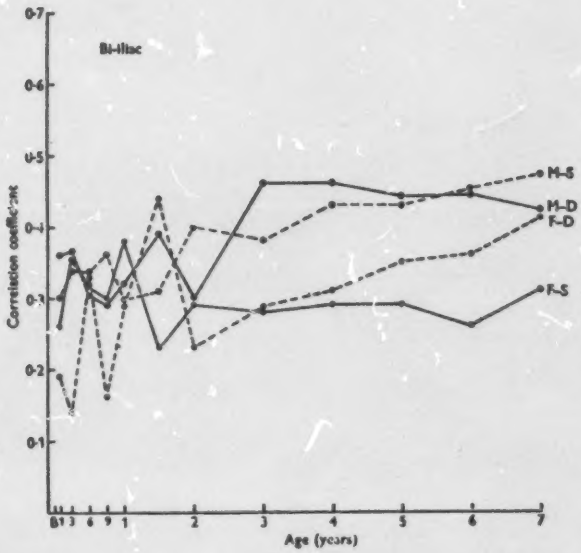

Fig. 4. Father-son (F-S), father-daughter (F-D), mother-son (M-S) and mother-daughter (M-D) correlation coefficients for bi-iliac diameter. F-S based on 30 pairs, F-D 27, M-S 60, M-D 57.

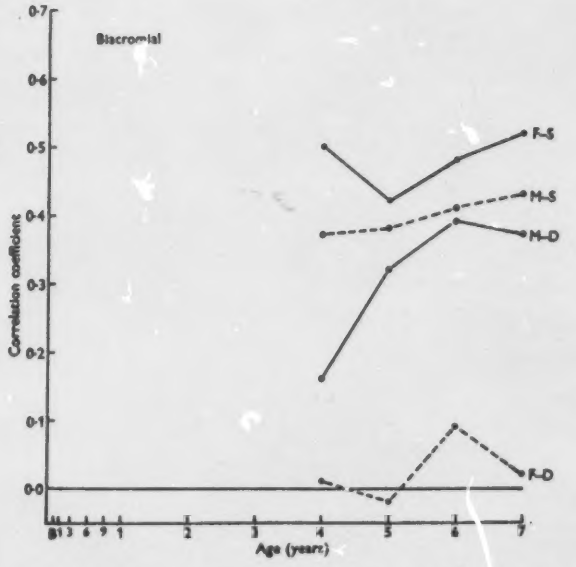

Fig. 5. Father-son (F-S), father-daughter (F-D), mother-son (M-S) and mother-daughter (M-D) correlation coefficient for biacromial diameter. F-S based on 30 pairs, F-D 27, M-S 60, M-D 57.

(c) Multiple correlations

The multiple correlations of child on both father and mother have been calculated for most of the measurements. They parallel the figures given in Table 1 very closely. They are on average only slightly higher since the mothers with husbands attending happened to correlate with their offspring less closely than those with husbands not attending. No essentially new information is contributed by these correlations.

DISCUSSION

There are two chief findings in this study:

(A) Most body measurements studied show a steep rise in parent-offspring correlation from the region of 0.2 at 1 month after birth to the region of 0.4 by age 2. From 2 to 7 a very gradual rise continues. Weight is an exception, being highest at 1 month, lowest at 9 months, and then rising to take its place with the other measurements by 2 years. Skinfold measurements of body fat at 3 to 7 show a parental correlation of only 0.1, which is insignificantly different from zero.

The explanation of this general rise from 1 month to 2 years is implicit in the results of Tanner *et al.* (1956) on the correlations between the measurements of children at birth, 1, 2, 3, 4 and 5 years and their own measurements as adults. In this study supine length, forearm length and head circumference showed correlations of the order of 0.2 to 0.3 between birth measurements and adult ones, but these rose swiftly to correlations of the order of 0.7 between measurements at age 2 and adult ones. Fig. 6 illustrates this for supine length and extends the age range with data from other

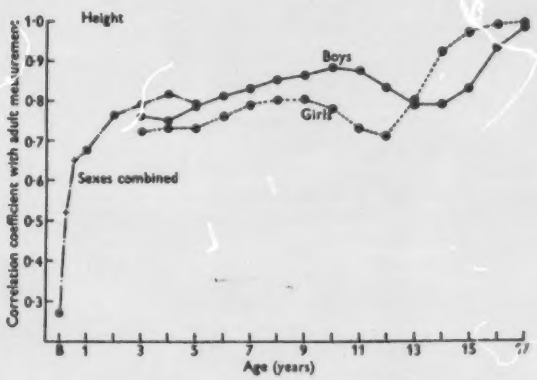

Fig. 6. Correlations between adult height and weight and heights and weights of same individuals as children. Sexes combined line (0-5) from 124 individuals of Aberdeen study (Tanner *et al.* 1956) with + points from Bayley (1954). Boys and girls' lines (3-17) from 66 boys and 70 girls of California Guidance Study (Tuddenham & Snyder, 1954). All data pure longitudinal. (From Tanner, *Growth at Adolescence,* second edition. Oxford: Blackwell Sci. Publ.)

similar studies. There is also little relation between a child's birth length and his or her length at 2 years, or even 1 year. From 2 years onwards, however, the year to year correlations stay relatively high.

It would seem therefore that the child's genes governing growth in size are not much expressed at birth, but rapidly assume importance during the first 2 years. By about age 3 we may suppose that most of the genes governing body size and shape are operative, apart perhaps from some governing the magnitude and character of the adolescent growth spurt.

An alternative explanation would be that during these first 3 years children differ in their degree of maturity, or percentage of adult size reached, more than they do later. Such an increase in variability certainly occurs at adolescence, and does then account for the decrease in adult-child correlations seen at that time and illustrated in Fig. 6 (Tanner, 1962). In like manner the brother-brother and sister-sister correlations become temporarily less at adolescence, as Palmer (1934) showed in a pioneer paper in this field. But there is no comparable increase in variability in the first 3 or 5 years, either of percentage of adult height achieved or of skeletal maturity (Bayley & Pinneau, 1952). For this reason we cannot agree with Hewitt (1957) when he seeks to account in this way for the lowness of the correlations in his Oxford material.

In pursuing this line of thought, however, Hewitt calculated the correlations between parents' height and child's skeletal maturity at ages 2, 3, 4 and 5, as assessed from wrist X-rays. He found, surprisingly, that the son's skeletal maturity was significantly related to the mother's adult height, tall women having sons who were advanced in development at ages 2 to 5. This was not true of tall women's daughters. A similar, though not quite significant, relation existed between fathers and daughters, but nothing between fathers and sons. We have confirmed the results in our data, using a new and, as we believe, more accurate method for estimating skeletal maturity (Tanner, Whitehouse & Healy, 1962). The correlation coefficients are given in Table 3; the numbers are somewhat lower than in the previous tables, but the parent-child correlations of this subsample were in all cases very close to those given by the whole sample. Like Hewitt's our mother-son correlations are significant, and probably differ significantly from the mother-daughter correlations. Again the father-daughter association is higher than the father-son.

Table 3. Correlation coefficients between height of parent and skeletal maturity score of child at ages 3 and 5

	No.	Age 3	Age 5
Father-son	21	—0.01	0.10
Father-daughter	15	0.30	0.14
Mother-son	40	0.40	0.39
Mother-daughter	40	0.18	0.10

Table 4. Correlation coefficients between height and skeletal maturity score of child

	No.	Age 3	Age 5
Boys	40	0.64	0.67
Girls	40	0.47	0.59

Table 5. Partial correlation coefficients between height of parent and height of child, skeletal maturity score of child being kept constant

	No.	Age 3	Age 5
Father-son	21	0.52	0.47
Father-daughter	15	0.14	0.13
Mother-son	40	0.23	0.22
Mother-daughter	40	0.53	0.59

This at once disposes of a possible explanation of our mother-daughter height correlation being higher than the mother-son. Height at age 3, say, is a reflexion both of ultimate adult height and of the rapidity with which it is being reached. A tall child at 3 may be a tall adult in the making, or he may be a short adult growing rapidly. Consequently the pattern of our height correlations could be explained if tall mothers had daughters, but not sons, who were fast developers. Table 3 shows that just the opposite is the case. Indeed, if the partial correlations between parent's height and child's height reduced to constant skeletal maturity are calculated (see Tables 4 and 5) the pattern of like-sex high correlations becomes still more marked than it was in Table 1. The chief effect of keeping skeletal maturity constant is to reduce the mother-son correlation towards that of the father-daughter.

The mechanism whereby tall women come to have early-maturing sons (at least to age 5) is not at all clear. It is important to remember that though skeletal advancement and height are related in children (Table 4) they are *not* so related in *adults*; on the contrary, there is a slight tendency towards a negative correlation, tall adults being on average late-maturing (Tanner, 1962). Thus one cannot simply say, with Hewitt (1957), that the pattern of correlation conforms to that produced by sex-linked genes: this would only be true if the correlations related parents' maturity instead of their height, or if parents' maturity and height were positively correlated. Nevertheless, some genetical explanation seems called for; it is very hard to explain these correlations by anything in the environment known to affect growth. Perhaps we are seeing some mechanism of balance in the control of growth and the genesis of parent-offspring resemblance.

Table 6. Correlation between weight of parent and skeletal maturity score of child at ages 3 and 5

	No.	Age 3	Age 5
Father-son	21	−0.10	−0.09
Father-daughter	15	0.25	0.63
Mother-son	40	0.26	0.20
Mother-daughter	40	0.04	0.03

Table 7. Correlation between weight and skeletal maturity of child

	No.	Age 3	Age 5
Boys	40	0.60	0.59
Girls	40	0.26	0.30

Table 8. Partial correlation coefficients between weight of parent and weight of child, skeletal maturity score of child being kept constant

	No.	Age 3	Age 5
Father-son	21	−0.16	−0.18
Father-daughter	15	0.28	0.03
Mother-son	40	0.21	0.39
Mother-daughter	40	0.63	0.42

In tables 6-8 the same series of correlations are given for parents' and children's weight and skeletal maturity scores. For parent's weight against child's skeletal maturity (Table 6) the unlike-sex correlations are higher than the like-sex, as for height. Holding the skeletal maturity constant decreases somewhat most of the child-parent weight correlations (Table 8) but leaves the pattern essentially the same as that of the original correlations of Table 1, which is rather different from the pattern for height.

(B) The second finding is that the mother-daughter correlations for supine length are above the mother-son correlations at all ages. All other published data agree with this and the sum total of all recorded observations leaves little doubt as to statistical significance. It is possible, though not certain, that the mother-daughter correlations are also above the mother-son correlations in the case of weight, after age 1. No such tendency is seen in bi-iliac or biacromial diameters.

There is some tendency in our data, and in Bayley's, for the father-son coefficient to be greater than the father-daughter coefficient for supine length, but we cannot be sure if this is statistically significant or not. In biacromial diameter at ages 4 to 7 a similar tendency, which does reach significant levels, is seen. In head circumference the reverse situation is encountered, the father-daughter correlations being the higher, though not quite to a significant degree.

These findings are most easily explained by supposing that there are sex-controlled genes operating even before puberty. There are a number of sex differences in body form which antedate puberty (see Tanner, 1962). There is also the difference in rate of skeletal maturation which has been shown to be influenced by genes on the *Y* chromosome either directly or through the intervention of some fetal hormone dependent on the genes on the *Y* chromosome (Tanner, Prader, Habich & Ferguson-Smith, 1959).

It would be surprising if the mother-daughter, mother-son difference disappeared by the time adulthood was reached; one would rather expect at puberty a further strengthening of the within-sex (father-to-son, mother-to-daughter) tie. Yet it is usually said that all four correlations in stature between parents and their grown-up offspring are equal and approximately 0.5. The same is said to be true of sitting height, leg length, arm length and head circumference: though some other measurements, notably head breadth and biacromial diameter, according to Bowles (1932) and Boas (see Tanner, 1959) have coefficients approximating 0.2 to 0.3. The date bearing on this question are surprisingly sparse, in fact, and distressingly old. All that we can find concerning stature are displayed in Table 9. Undoubtedly the most accurate set is that reported by Durnin & Weir (1952) on Glasgow medical students. Calculations on these data, kindly supplied to one of us some years ago by Dr Durnin, show that the mother-daughter correlation is higher than the mother-son (Table 9). Likewise the father-son correlation is higher than the father-daughter. Neither of these differences reaches a significance level beyond $P = 0.20$ in a comparison which neglects the fact that in each case one element (mothers or fathers) is common to both coefficients. If this could be adequately allowed for, the differences might approach the 5% level.

Table 9. Parent-offspring correlations reported for stature; offspring adult

Author	Father-son	Father-daughter	Mother-son	Mother-daughter
Pearson & Lee (1903)	0.51 ± 0.02	0.51 ± 0.02	0.49 ± 0.02	0.51 ± 0.02
Galton, 1899 data calculated by Finney (1939)	0.52 ± 0.08	0.49 ± 0.08	0.36 ± 0.08	0.37 ± 0.08
Durnin & Weir (1952) data calculated by Tanner	0.55 ± 0.07	0.42 ± 0.13	0.37 ± 0.07	0.52 ± 0.13
Hathaway & Ford (1960) data of Meyer	—	0.51 ± 0.03	—	0.49 ± 0.03

Pearson & Lee data on students and self-measured families.
Galton data self-measured with dubious technique and sometimes only estimated.
Durnin & Weir, Glasgow students; parents measured by student.
Hathaway & Ford, records of Vassar College girls and parents, self-measured.
We are unable to find a copy of Bowles's (1932) data. The data of Boas (Tanner, 1959) and those reported by Grab (1956) are of interest but have not been calculated in this form.

The partial regressions are:

daughter's stature = 0.24 (± 0.08) father's + 0.39 (± 0.09) mother's + constant;
and son's stature = 0.46 (± 0.06) father's + 0.32 (± 0.07) mother's + constant.

The difference here between father-son and father-daughter is significant at 2%. Similarly the son's regression on the father is significantly greater than his regression on the mother. Galton's data, reported by Finney (1939) agree with this in showing the father-son correlation and regression as significantly higher than the mother-son.

There is thus some doubt as to what really is the true situation in adults, and more information is badly needed. Bayley's data, surprisingly, show the mother-son and father-daughter coefficients increasing from about 0.35 at 7 to the figure of 0.5 at about 17 and staying there into adulthood. Her material is too small for any strong conclusions to be drawn from it. It would be strange indeed if the expression of the genes controlling the adolescent spurt were not affected by the individual's hormonal background. Sex-control, and hence father-son and mother-daughter similarity, would be expected to increase and not to disappear at adolescence. We hope to report at a later date on what happens at that time in our material.

SUMMARY

Measurement of height, weight, sitting height, biacromial and bi-iliac diameters, bicondylar diameters of humerus and femur, upper arm circumference, and four skinfolds have been taken on a pure longitudinal series of 117 children at intervals from 1 month to 7 years, on the mothers of all of them and on the fathers of 57. The father-son, father-daughter, mother-son and mother-daughter correlation coefficients have been calculated at successive ages of the children.

Most of these measurements show a steep rise in parent-offspring correlation from the order of 0.2 at 1 month to the order of 0.4 at 2 years; from 2 to 7 a very gradual rise continues. Weight is an exception, the correlation being highest at 1 month, lowest at 9 months and subsequently rising. The parent-offspring correlation for skinfolds from 3 to 7 years is only about 0.1, which does not differ significantly from zero.

The mother-daughter correlations for supine length in this age range are significantly above the mother-son correlations. The same may also be true for weight after age 1, though the statistical significance is not fully established. In bi-iliac and biacromial diameters no such sex difference occurs. The father-son coefficient is greater than the father-daughter coefficient for supine length, though not to a significant degree. The father-son coefficient for biacromial diameter from 4 to 7 years is significantly above the father-daughter coefficient.

The conclusion is drawn that there are sex-controlled genes affecting physique operating even before puberty. As there are usually supposed to be no mother-daughter, mother-son, etc., correlation differences in adulthood, the question is raised as to when and how these differences may be eliminated from 7 to 17 years. The published adult figures are also reexamined, with the conclusion that the supposed equality of the four parent-child coefficients is much less securely based on evidence than is generally thought.

There is a statistically significant correlation between skeletal maturity as assessed from wrist X-rays at ages 3 and 5 of sons and the height of their mothers. Thus tall mothers have advanced sons; but they do not have advanced daughters. Similarly tall fathers have somewhat advanced daughters, but not sons. The cause of these correlations is not yet clear; in the adult there is no positive correlation between height and previous advancement in maturity.

We wish to thank Mr. Howard Simpson, Mr. R. H. Whitehouse, Mrs. Shelagh Orton and Mr. John Harris for much welcome computational help.

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Evolution clinique de la puberté de la fille *

(Étude longitudinale somatique de 80 adolescentes)

M.-P. Roy, M. Sempé **, E. Orssaud *, G. Pedron**

La description et le déroulement des phénomènes pubertaires chez la fille ont déjà fait l'objet de nombreux travaux. La biométrie seule ne suffit certes pas pour juger de l'évolution de la puberté, mais les transformations qui surviennent lors de cette période sont si importantes qu'elles doivent être systématiquement notées et étudiées.

Les modes d'analyse des critères biométriques sont multiples, et il ne peut être question de résumer ici des travaux fondamentaux comme ceux de Bayer et Bayley (2), Falkner (6), Royer et Masse (5, 16), Tanner (19), Lelong et ses collaborateurs (11, 12), pour n'en citer que quelques-uns.

Beaucoup de ces auteurs ont fait une analyse statique tranversale de ces phénomènes, mais c'est l'étude longitudinale récente de quelques caractères propres à cette période, permettant une analyse dynamique, qui constitue l'originalité de l'enquête présentée ici.

Précisons tout de suite qu'au cours d'une étude longitudinale l'une des préoccupations essentielles est celle de la conservation de l'échantillon pendant une période de longue durée. C'est pourquoi, dans la crainte d'importuner les enfants, tous les examens biologiques ont été systématiquement exclus, malgré le grand intérêt qu'ils présentent. Il est certain que cette lacune est très regrettable.

MÉTHODOLOGIE

L'équipe parisienne qui a réalisé ce travail collabore depuis 18 ans avec six autres équipes (européennes, africaine et américaine) à une étude longitudinale sur la croissance de l'enfant coordonnée par le Centre international de l'Enfance (F. Falkner).

Chacun de ces groupes a adopté les mêmes types d'examens, qui se font régulièrement tous les 6 mois ou au moins une fois par an et qui comportent :

1) Une série de mesures anthropométriques, dont nous ne retiendrons ici que la longueur couchée, les deux mesures de taille segmentaire : segment supérieur et segment inférieur, et celle de deux diamètres transversaux : diamètre biacromial et bi-iliaque.

L'étude de la vitesse de croissance en taille a été faite sur toutes les courbes individuelles obtenues à partir des mesures de longueur couchée.

Cette vitesse de croissance a toujours été calculée d'année en année pour éviter l'interférence des variations saisonnières. Mais pour chacun des sujets, deux courbes de vitesse de croissance ont été simultanément tracées : l'une en fonction de la vitesse de croissance calculée d'anniversaire à anniversaire, et l'autre en fonction de la vitesse calculée de mi-année à mi-année. Dans les deux cas, l'âge chronologique porté en abscisse est celui qui correspond à l'âge atteint au milieu de chaque période de temps considéré.

Ce mode de représentation nous semble intéressant : il permet d'extérioriser avec précision les variations de la vitesse de croissance, et en particulier de noter la forme du pic, sa hauteur, et de connaître l'âge auquel il apparaît avec une approximation de plus ou moins 3 mois.

Le segment supérieur a toujours été mesuré en position couchée, et la longueur du segment inférieur a été calculée par simple différence entre longueur totale et segment supérieur.

Les deux diamètres transversaux ont été mesurés à l'aide d'un compas d'épaisseur à boule.

Les repères osseux choisis sont le bord externe des acromions pour le diamètre biacromial, et la partie externe la plus saillante des crêtes iliaques pour le diamètre bi-iliaque.

Le rapport DA/DC, qui est un indice de maturation important, a été calculé pour chaque sujet à chaque âge.

2) La date d'apparition des premières règles a été obtenue par interrogatoire et nous sommes certains de sa précision au mois près : l'interrogatoire de ces sujets, avec qui nous sommes en confiance depuis des années, lui confère une sûreté qui ne peut être mise en doute.

Mais, bien entendu, cette date ne précise pas celle de la première ovulation. L'étude des simples courbes thermiques aurait pu nous fournir des renseignements à ce sujet, mais nous avons craint que ces jeunes adolescentes ne s'astreignent pas à les faire avec la rigueur voulue, et que les courbes perdent ainsi de leur valeur.

3) Les caractères sexuels secondaires ont été estimés par la méthode d'observation directe, et la codification adoptée pour discriminer les différents stades est celle décrite par Tanner (19).

4) La maturation osseuse au niveau du poignet et de la main a été évaluée sur les radiographies par la méthode de Tanner et Whitehouse (20) pour chaque sujet par le même examinateur, et toutes les notes obtenues ont été portées sur une courbe. Cette courbe similaire à une courbe de taille a permis d'attribuer une note de maturation aux dates où les sujets avaient manqué un examen ou possédaient un cliché techniquement illisible : ces valeurs portent le nom de valeur calculée.

Pour un certain nombre de filles examinées, l'analyse a été faite en dissociant la maturation des os longs de celle des os du carpe.

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* Nous remercions les Editions Doin, Paris, qui ont donné l'autorisation de reproduire cet article paru dans «Archives Françaises de Pédiatrie», 1972, 29, 155-168.

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MATÉRIEL

L'échantillon étudié se compose d'un groupe de 80 filles nées à Paris, pour la plupart entre 1953 et 1955, et qui ont été recrutées selon des modalités très précises relatées dans la thèse de l'un d'entre nous (M. Sempé) (17).

Ces enfants sont nés de parents français qui habitaient au moment de leur naissance un secteur géographique précis comprenant à Paris le XIV[e] et une partie du XV[e] arrondissement et trois communes avoisinantes de banlieue.

Il s'agit d'enfants qui ne présentaient aucune malformation apparente à la naissance et leur poids de naissance oscillait entre 2,3 kg et 4,7 kg.

Si le critère de sélection choisi est le poids de naissance et non la durée de la gestation, c'est que cette étude a été entreprise en 1953-1955, date à laquelle la distinction entre prématurité et dysmaturité n'était pas encore codifiée avec autant de rigueur qu'actuellement.

Cependant, la date des dernières règles précédant la grossesse figure sur les interrogatoires faits à la maternité lors du recrutement, mais les renseignements recueillis ne nous ont pas paru assez précis pour être retenus.

L'environnement familial et social de ces enfants ainsi que le niveau de vie de leurs parents ont été étudiés et codifiés: la plupart d'entre elles appartiennent aux classes III et IV de la classification Graffar (10), c'est-à-dire aux classes moyenne et moyenne-inférieure.

L'assiduidé aux examens de toutes ces enfants a été suffisante pour permettre une observation satisfaisante depuis la naissance jusqu'à la puberté accomplie.

Il faut ajouter aussi qu'aucune affection intercurrente grave pouvant retentir de façon durable sur la croissance n'a été observée parmi les enfants du groupe étudié.

RÉSULTATS

1) *La vitesse de croissance en taille.*

Elle présente des variations qui sont de deux ordres et que résume le tableau suivant:

TABLEAU 1 Vitesse annuelle de croissance en taille

	Valeur (cm)		Age	
	Moyenne	Ecart-Type	Moyenne	Ecart-Type
Vitesse minima.....	4,7	0,65	9 ans 4 mois	1 an 1 mois
Vitesse maxima.....	8,4	0,95	12 ans	11 mois

Ainsi, à une période prépubertaire caractérisée par un minimum de vitesse de croissance succède une accélération de la vitesse de croissance, qui passe par un maximum se traduisant par un pic caractéristique.

Forme du pic.

Dans la grande majorité des cas (80 %), une seule des deux courbes de vitesse tracée (anniversaire à anniversaire, et mi-année à mi-année) présente un pic caractéristique, c'est-à-dire que la période d'accélération maxima a été brève, se limitant à une année.

Dans 17 % des cas, l'aspect du pic est différent: les deux courbes peuvent monter exactement au même niveau et l'âge du pic est celui qui correspond au milieu des deux sommets; le pic peut être plus étalé encore, formant en quelque sorte un «dôme» avec trois points successifs au même niveau: on choisit comme âge du pic l'âge correspondant au milieu du dôme. Ces diverses éventualités sont représentées sur le graphique 1.

Hauteur du pic.

Elle est en moyenne de 8,4 cm, avec des valeurs extrêmes oscillant entre 6,3 et 12 cm dans un cas.

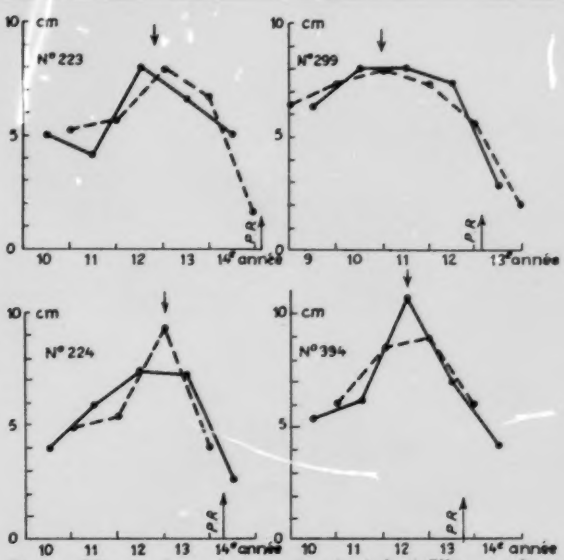

Fig. 1. Vitesse de croissance (cm/an) de 4 filles pendant la puberté.

2) *Diamètre biacromial, diamètre bi-iliaque et leur rapport.*

Le tableau 2 donne la valeur moyenne de ces deux mesures aux différents âges, ainsi que celle de leur rapport. Ce dernier augmente progressivement de 8 à 10 ans, reste stable pendant 2 ans, puis diminue régulièrement (tableau 2).

Marshall et Tanner (13) et à celles de l'étude longitudinale de Zurich (4).

Nous n'avons pas calculé de moyenne pour S5 et P5, toutes les filles n'ayant pas encore atteint ce stade. Les stades se succèdent donc en moyenne à un intervalle d'un an, mais la durée de cette période intermédiaire d'un stade à l'autre est très variable selon les sujets. La

TABLEAU 2 Moyenne et écart-type

Age	Nombre de sujets	Axe biacromial		Axe bi-iliaque		$\frac{\text{Axe biacromial}}{\text{Axe bi-iliaque}} = \frac{DA}{DC}$	
		M (cm)	E. T.	M (cm)	E. T.	M	E. T.
7 ans	80	25,4	1,29	19,3	1,18	1,32	0,06
7 ½	80	25,8	1,22	19,6	1,20	1,32	0,06
8 ans	80	26,2	1,23	19,9	1,23	1,31	0,06
8 ½	80	26,8	1,20	20,3	1,23	1,31	0,06
9 ans	80	27,3	1,21	20,6	1,27	1,32	0,06
9 ½	80	27,9	1,26	20,9	1,32	1,33	0,07
10 ans	80	28,5	1,41	21,2	1,42	1,34	0,07
10 ½	80	29,1	1,49	21,6	1,46	1,34	0,07
11 ans	80	29,7	1,53	22,1	1,55	1,34	0,07
11 ½	80	30,5	1,52	22,8	1,56	1,34	0,06
12 ans	80	31,4	1,61	23,5	1,72	1,35	0,07
12 ½	77	32,2	1,53	24,1	1,67	1,33	0,07
13 ans	76	32,9	1,38	24,8	1,64	1,32	0,07
13 ½	73	33,5	1,39	25,3	1,66	1,32	0,07
14 ans	71	34,0	1,46	25,7	1,65	1,32	0,07
14 ½	62	34,3	1,33	26,1	1,63	1,31	0,06
15 ans	55	34,6	1,38	26,4	1,64	1,31	0,06

3) *Age d'apparition des premières règles.*

L'âge moyen d'apparition des premières règles dans le groupe est de 13 ans (ET : 10 mois et demi), avec des âges extrêmes allant de 10 ans 7 mois à 15 ans 4 mois. La répartition de l'âge d'apparition des premières règles en pourcentage cumulatif de 6 mois en 6 mois est schématisée dans le graphique 2. Pratiquement, 50 % des filles sont réglées avant 13 ans, et 16 % ne le sont pas encore à 14 ans.

La taille moyenne, au moment de l'apparition des premières règles, est de 155 cm (ET : 5,8). Quant au poids moyen, il est de 43,9 kg, et dans notre échantillon la dispersion du poids est très grande, variant de 32 kg à 60 kg à l'âge des premières règles.

4) *Chronologie des caractères sexuels secondaires.*

Les caractères sexuels secondaires sont beaucoup plus variables que la vitesse de croissance en taille dans leur rythme et leur durée. Le tableau 3 montre que les moyennes d'âge d'apparition des différents stades dans notre groupe sont très semblables à celles publiées par

dispersion des âges extrêmes est un peu moins grande pour S2 et S3 que pour P2 et P3 : 3 ans et demi à 4 ans au lieu de 5 ans. Dans l'ensemble, S3 et P3 sont à peu près contemporains du pic, S4 et P4 contemporains des règles.

La chronologie de l'évolution pubertaire au sein de notre groupe est résumée dans le graphique 3 qui donne la moyenne d'âge d'apparition de chaque critère avec ses valeurs extrêmes. Nous y avons inclus en outre l'apparition de trois repères osseux considérés comme très importants au cours de la puberté : le pisiforme et les deux os sésamoïdes du pouce.

5) *Corrélation entre maturation osseuse et âge des premières règles* (analyse préliminaire).

Connaissant de façon précise l'évolution de la maturation osseuse au niveau du poignet et de la main, pour chaque sujet, depuis la naissance, nous avons cherché à savoir s'il existait dès la première enfance une corrélation entre maturation osseuse et âge des premières règles. Nous avons choisi arbitrairement les âges de 4, 7 et 10 ans.

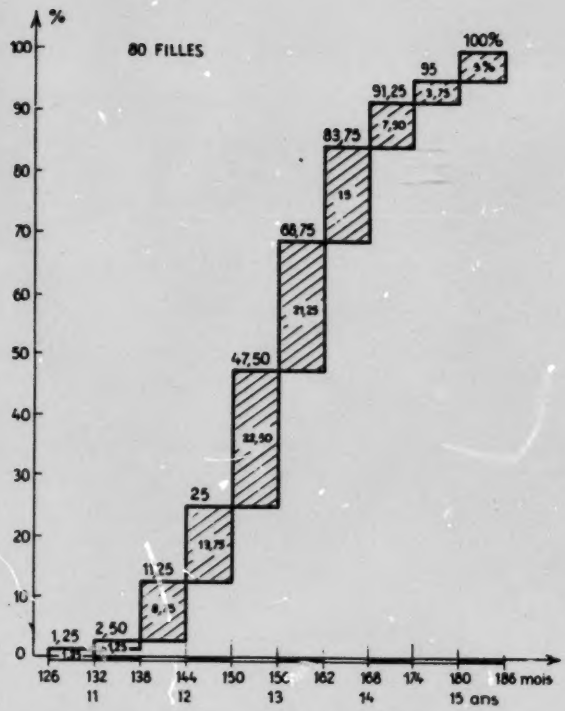

Fig. 2. Pourcentages cumulés des premières règles selon l'âge de leur survenue.

TABLEAU 3
Age d'apparition des stades pubertaires

	Moyenne (année)		
	Zurich	Londres	Paris
Premières règles	12,75	13,47	13,01
Pic de croissance	11,72	12,14	12,00
S_2 : 1re observation 2e observation	10,90 11,71	11,15	11,40
P_2 : 1re observation 2e observation	10,72 11,45	11,69	11,35
S_3	11.92	12,15	12,50
P_3	11,65	12,36	12,36
S_4	13,00	13,11	13,42
P_4	12,58	12,95	13,20

Les résultats inscrits dans le tableau 4 ne montrent aucune corrélation significative à 4 ans dans les deux groupes, valeurs réelles et valeurs calculées. A 7 ans, le coefficient de corrélation (r) devient significatif seulement dans le cas où il est calculé avec les valeurs réelles. A 10 ans, il est significatif dans les deux cas.

Pour analyser de façon plus précise les corrélations constatées entre maturation osseuse et âge des premières règles à partir de 7 ans, un travail a été fait sur le seul échantillon strictement longitudinal des 37 filles présentes à tous les examens et ayant un cliché lisible à chaque âge, 7, 8, 9 et 10 ans.

Dans ce sous-groupe, l'analyse de la maturation osseuse a été faite en dissociant la maturation des os longs de celle des os du carpe, et le tableau 5 résume les coefficients de corrélation obtenus à chaque âge. D'après ces résultats préliminaires, la corrélation qui existe entre maturation osseuse et âge des premières règles serait essentiellement imputable à la maturation des os longs.

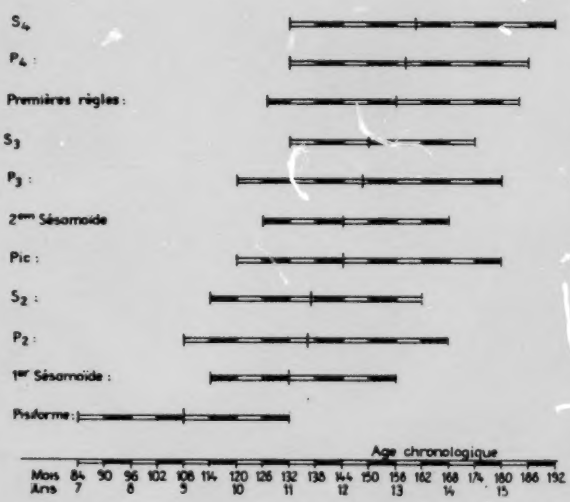

Fig. 3. Chronologie des signes pubertaires (moyenne et âges extrêmes).

TABLEAU 4
Coefficient de corrélation entre l'âge osseux à 4, 7 et 10 ans et l'âge des premières règles.

Age	Coefficient de corrélation sans tenir compte des valeurs calculées	Coefficient de corrélation en tenant compte des valeurs calculées
4 ans	$n = 60$ $r = -0,07$	$n = 83$ $r = -0,04$
7 ans	$n = 54$ $r = -0,37^{**}$	$n = 83$ $r = -0,17$
10 ans	$n = 62$ $r = -0,45^{***}$	$n = 83$ $r = -0,38^{***}$

* = P < 0,05
** = P < 0,01
*** = P < 0,001

TABLEAU 5
Corrélation entre maturation osseuse et âge aux premières règles pour 37 filles examinées à 7, 8, 9 et 10 ans (méthode de Tanner Whitehouse)

	7 ans	8 ans	9 ans	10 ans
Os carpe	-0,29	-0,26	-0,34 -	-0,36 -
Os longs	-0,44 --	-0,49 --	-0,40 -	-0,50 --
Total	-0,46 --	-0,46 --	-0,41 -	-0,48 --

\- = corrélation négative au seuil de 0,05
-- = corrélation négative au seuil de 0,01

DISCUSSION

Il est très important de souligner qu'il ne saurait être question de donner à tous les chiffres moyens cités dans l'étude de ce groupe une valeur de norme. L'échantillon de départ n'a pas été standardisé par rapport à la population parisienne. De plus, au cours des années, il a pu subir des distorsions.

En effet, la poursuite de telles enquêtes pendant un laps de temps aussi long se heurte à de multiples difficultés, et de nombreuses défections ont considérablement réduit le groupe primitif, qu'il s'agisse d'abandons définitifs ou d'absences prolongées, qui rendent certains dossiers inexploitables.

Cependant, il est intéressant de constater qu'à 5 et 7 ans, par exemple, les moyennes de poids et de taille de notre échantillon global sont tout à fait comparables à celles établies par le Service de Santé scolaire et universitaire au cours de la vaste enquête effectuée en 1955 parmi les écoliers français (7).

Le groupe restreint des 80 filles étudiées ici ne diffère pas non plus de l'ensemble (113 filles à 7 ans) de façon notable. Seule la répartition des niveaux sociaux accuse une légère différence avec la répartition dans l'échantillon global : il est indéniable que ce sont dans les classes IV et V, c'est-à-dire moyenne-inférieure et inférieure, que les défections ont été plus nombreuses, et de ce fait l'ensemble des conditions de vie des enfants de cet échantillon restreint est plus favorable que celui du groupe total. Mais, au cours d'une enquête longitudinale, c'est l'analyse dynamique des caractères qui confère à l'étude toute sa valeur.

Ainsi, l'étude de la vitesse de croissance en taille garde toute sa précision : la phase d'inhibition physiologique précédant immédiatement celle d'accélération pubertaire était déjà signalée par Hagen (18), et elle semble très intéressante à retenir. Elle précède toujours l'apparition des caractères sexuels secondaires, mais elle est très dispersée dans le temps, pouvant survenir entre 7 ans et demi et 11 ans.

De plus, elle reste difficile à situer sur un certain nombre de courbes. C'est pourquoi il faut attacher au « pic » une valeur de première importance : il est pratiquement constant, puisque dans notre groupe il n'a été absent que dans un cas et douteux dans un autre.

Sa dispersion dans le temps est très grande aussi, allant de 10 ans à 15 ans. Ces chiffres rejoignent tout à fait ceux rapportés sur le schéma publié par Tanner en 1962 (19).

Il faut ajouter que l'analyse des courbes de vitesse de tailles segmentaires : segment supérieur et segment inférieur, faites par G. Duval-Beaupère, permet de préciser que c'est l'accélération de la croissance rachidienne qui est seule responsable de ce pic (travail en cours de publication aux *Archives Françaises de Pédiatrie*). La vitesse de croissance du segment inférieur reste constante, et il n'a été observé de pic sur les membres inférieurs que dans un seul cas.

Quant à la distribution de la hauteur du pic en fonction de l'âge, elle montre qu'il existe une faible corrélation entre ces deux variantes : $r = -0,26$. Il n'en est pas de même chez les garçons où l'étude préliminaire des 59 courbes individuelles nous a permis de mettre en évidence une corrélation plus nette entre ces deux phénomènes : $r = -0,41$.

Le rapport DA/DC ne commence à diminuer régulièrement dans notre échantillon qu'à partir de 12 ans, alors que pour d'autres auteurs comme Twiesselmann (21), c'est dès l'âge de 9 ans qu'est observée chez les filles une diminution rapide de ce rapport : le diamètre bi-iliaque commence à croître dès cet âge plus rapidement que le diamètre biacromial.

Une analyse ultérieure devra donc étudier la vitesse de croissance de chacun de ces deux diamètres pour

pouvoir les comparer avec précision. Il ne faut pas oublier non plus que le diamètre biacromial est une mesure difficile qui varie beaucoup avec la position du sujet. Les erreurs de mesure y sont beaucoup plus nombreuses que dans la mensuration du diamètre bi-iliaque qui est très fidèle.

L'âge moyen d'apparition des premières règles dans notre groupe (13 ans) permet de le situer parmi d'autres populations. Il est un peu plus précoce que celui donné en France par Aubenque (1) en 1950 (pour cet auteur, à 13 ans, il n'y a que 44 % des filles réglées) et Boltanski (3) en 1961. Cela tend à confirmer l'avance séculaire de l'âge moyen d'apparition des premières règles. Ce phénomène signalé sur le plan mondial est dû sans doute à l'amélioration des conditions de vie et à certains facteurs jouant très précocement, comme le rapport Van der Werff ten Bosch (22).

Dans tous les cas, les premières règles sont survenues après le pic de croissance en taille, au cours de la période de décélération, avec un délai très variable pouvant aller de 1 à 29 mois, le délai moyen entre ces deux phénomènes caractéristiques, pic et règles, étant de 13 mois. Il semble que cet intervalle soit dans l'ensemble plus bref chez les filles réglées précocement, et plus long chez celles qui le sont tardivement, mais cette différence n'a pas été testée statistiquement.

La codification de Tanner adoptée pour l'étude des caractères sexuels secondaires a l'avantage d'être reconnue sur le plan international, mais elle laisse subsister un certain coefficient d'appréciation subjective. Aussi l'interprétation de nos résultats est-elle difficile, étant donné le nombre élevé d'examinateurs qui se sont succédé au cours de l'enquête.

D'autre part, un rythme d'examen bisannuel ou parfois annuel seulement est insuffisant pour une telle observation, d'autant qu'aucune interpolation n'est possible dans ce domaine.

Enfin, dans les études de Londres et Zurich, la codification a été faite sur les photographies des sujets prises à chaque examen. Dans notre groupe, l'observation a été directe. Les résultats sont cependant assez concordants, et il ne semble pas qu'il y ait de différence notable entre ces deux méthodes d'observation.

Nous ne discuterons pas ici de la valeur des diverses méthodes d'évaluation de la maturation osseuse et des raisons pour lesquelles c'est celle de Tanner et Whitehouse qui a été choisie dans cette enquête. Une étude détaillée de la maturation osseuse pendant la période pubertaire fait l'objet du travail de l'un d'entre nous (en cours de préparation).

Notons cependant que pour 49 filles le degré de maturation osseuse a été calculé au moment de l'apparition des premières règles. A ce stade précis, l'âge osseux varie dans cet échantillon entre 11 et 14 ans, la médiane étant à 13 ans. Sa dispersion reste donc importante, mais elle est un peu moindre que celle de l'âge réel au moment des premières règles: 11 ans 4 mois à 14 ans 10 mois pour ces 49 mêmes sujets.

Il reste à chercher si l'évolution de la maturation osseuse permet de prédire l'âge d'apparition des premières règles. En 1969, Frisancho, Garn et Rohmann (8) proposaient de faire cette prédiction à partir d'une équation mathématique incluant la date d'apparition du 1er sésamoïde et celle de la fusion de l'épiphyse distale de l'index. Mais ces deux événements sont tardifs et font déjà partie de l'évolution pubertaire.

C'est peut-être la maturation des os longs qui peut apporter précocement un élément d'information sur l'évolution pubertaire ultérieure, mais ceci demande à être confirmé: aussi intéressante que soit cette corrélation, elle est difficile à interpréter.

Seule la moindre importance des os du carpe a déjà été signalée: Garn et Rohmann (9) estiment que scaphoïde, trapèze et trapézoïde ont moins de valeur parce que leur séquence d'apparition est variable, et Massé (14, 15) constate que les facteurs intrinsèques d'environnement influent davantage sur les épiphyses des os longs que sur les os du carpe.

CONCLUSION

La puberté survient à des âges extrêmement variables: un échantillon aussi restreint que celui de cette enquête longitudinale le confirme.

Cependant, le déroulement de cette période se reproduit de façon analogue d'un sujet à l'autre, et son ordre est bien défini: le pic de croissance en taille, souvent contemporain de P3 et S3, reste «l'événement» le plus fidèle qui précède l'apparition des premières règles. C'est dire toute l'importance que prend en clinique la courbe de taille à cette période, mais en l'absence de mensurations régulières (tous les six mois) ce pic reste méconnu.

La maturation osseuse au cours de cette phase pubertaire doit être encore explorée à la recherche d'une corrélation précise entre son évolution et celle de la puberté. Cela nécessite une étude systématique de tous les indicateurs possibles: os longs et os du carpe, et seules des enquêtes longitudinales peuvent apporter une réponse à ce problème.

Quant à l'évolution des caractères sexuels secondaires, elle reste difficile à interpréter, puisque les séquences observées chez des sujets parfaitement normaux sont très variables. Développement mammaire et pilosité pubienne évoluent simultanément dans 38 % des cas. Mais la pilosité pubienne (P2) reste isolée au début, en l'absence de tout développement mammaire, dans 29 % des cas, et même deux fois le stade P3 a été atteint sans qu'aucune modification ne soit notée au niveau des seins. Réciproquement, dans un tiers des cas c'est le bourgeon mammaire (S2) qui se développe seul pendant au moins un an, en l'absence de toute pilosité pubienne.

RÉSUMÉ

Cette enquête porte sur l'évolution de la puberté chez 80 filles nées à Paris, pour la plupart entre 1953 et 1955, et régulièrement suivies selon la technique longitudinale.

L'étude de la vitesse de croissance en taille montre que la période prépubertaire est caractérisée par une vitesse minime (4,7 cm en moyenne) à un âge moyen de 9 ans 4 mois. Une période d'accélération de la vitesse de croissance lui succède, se traduisant par un «pic» observé à 12 ans et atteignant 8,4 cm en moyenne.

L'âge moyen des premières règles est de 13 ans dans le groupe, mais 16 % des filles ne sont pas encore réglées à 14 ans.

La maturation osseuse est un indicateur essentiel à cette période, et, selon une étude préliminaire qui demande confirmation, il y aurait dès la période prépubertaire une corrélation entre la maturation des os longs et l'âge des premières règles.

Les caractères sexuels secondaires sont très variables dans leur évolution, mais le plus souvent S3 et P3 sont contemporains du pic, S4 et P4 des premières règles.

SUMMARY

This is a study of the evolution of puberty in 80 girls born in Paris mostly between 1953 and 1955 and regularly followed according to the longitudinal method.

Height velocity is minimal during the prepuberal period (average 4.7 cm per year) at a mean age of 9 years and 4 months. The peak height velocity occurs at 12 years; its average value is 8.4 cm per year.

The mean menarchal age is 13 years in that group but 16% of the girls have not yet menstruated at 14 years.

Bone maturation is a basic indicator during puberty. A preliminary study which needs confirmation showed that there is a correlation between bone maturation during the prepuberal period and age at menarche.

Secondary sex characteristics showed great variability, but in general S_3 and P_3 coincided with the peak height velocity and S_4 and P_4 are related to menarche.

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Age de la marche et facteurs associés étudiés dans un échantillon longitudinal de 296 enfants parisiens (*)**

E. Patois, M.-P. Roy, M. Sempé, J. Lellouch

Alors que le développement moteur de l'enfant a donné lieu à une immense littérature, il n'y a qu'un nombre relativement restreint d'études portant sur l'âge du début de la marche et les facteurs qui pourraient lui être associés, dans des groupes d'enfants normaux. Le premier travail semble être celui de Smith *et al.* (23). Ses résultats ainsi que ceux des quelques travaux ultérieurs seront commentés dans la discussion. De façon générale, on peut dire qu'ils sont assez souvent discordants. Comme d'autre part certaines des études peuvent être entachées de biais, dans la mesure où les renseignements concernant l'âge du début de la marche ont été obtenus de façon rétrospective, parfois après un long délai, il a paru utile de réexaminer la question dans un échantillon d'enfants suivis longitudinalement.

MATÉRIEL ET MÉTHODES

La population étudiée est constituée par l'échantillon parisien des enquêtes sur la croissance de l'enfant normal, coordonnées par le Centre international de l'Enfance. Les buts et les méthodes de cette enquête ont été largement décrits ailleurs (4); nous nous limiterons ici aux aspects qui concernent plus spécifiquement notre problème.

Il s'agit d'un groupe d'enfants ne présentant aucune malformation apparente et dont le poids de naissance était supérieur ou égal à 2500 g.

Ces enfants ont été examinés à l'âge de 1 mois, 3 mois, 6 mois, 9 mois, 1 an puis tous les six mois.

L'âge de la marche a été obtenu par interrogatoire de la mère; la marche est définie comme la possibilité de faire plusieurs pas successifs, tout à fait seul et sans appui.

A chacun des examens on a mesuré le poids P, la taille couchée T, le segment supérieur (le segment inférieur étant obtenu par différence) et les quatre plis cutanés (PC) suivants à l'aide de la pince de Harpenden; prébicipital, rétro-tricipital, sous-scapulaire, supra-iliaque. On a estimé l'«obésité» au moyen des indices suivants:

1. L'indice de corpulence: $IC = \log \frac{P}{T^2}$ ($\frac{P}{T^2}$ est l'indice de Quetelet: la puissance 2 de la taille assure une quasi-indépendance statistique entre la taille et IC, qualité éminemment désirable pour un indice d'obésité);

2. Le pourcentage de graisse: $p = \left(\frac{4,95}{d} - 4,5\right) \times 100$ (formule de Siri) (22) où la densité corporelle d est elle-même estimée par $d = 1,1533\text{-}0,0643 \log \Sigma$ (plis cutanés) pour les garçons et $d = 1,1369\text{-}0,0598 \log \Sigma$ (plis cutanés) pour les filles (formules de Durnin et Rahaman) (3).

Le pourcentage de la masse grasse étant ainsi calculé, on a obtenu les valeurs absolues des masses grasse et maigre de chaque sujet.

Masse grasse MG = p × P et Masse maigre MM = P — MG.

L'âge osseux a été mesuré sur un échantillon trop restreint pour pouvoir être étudié dans le présent travail.

On a également retenu les mesures effectuées, aux âges de 2 et 3 ans du quotient de développement (QD) d'après le test de Brunet-Lézine, et aux âges de 5, 8 et 10 ans, du quotient d'intelligence (QI) d'après le test de Termann-Merill.

Enfin, un examen clinique et l'anamnèse des maladies intercurrentes ont été faits à chaque visite.

On a également noté l'âge d'apparition de la première dent de lait. Une enquête sociale faite à la naissance de l'enfant a permis de préciser le niveau social de la famille selon la classification mise au point par Graffar (4) et basée sur la profession du chef de famille, le niveau d'instruction des parents, les revenus familiaux, le confort du logement et l'aspect du quartier habité. Quant aux conditions de l'accouchement elles avaient été relevées à la maternité ainsi que le poids de naissance.

Seuls ont été retenus dans l'étude les enfants qui ont été suivis jusqu'à l'âge de 3 ans. En effet, conserver — comme cela est habituellement fait dans les travaux similaires — tous les enfants pour lesquels on a pu noter l'âge de la marche, risque d'introduire un biais dans la distribution de cet âge, dans la mesure où les enfants qui marchent tard ont plus de chance d'être éliminés de l'étude que ceux qui marchent tôt.

296 enfants ont ainsi été étudiés (163 garçons et 133 filles). Tous n'ont pas été présents aux différents examens. S'il nous a paru possible à partir des courbes individuelles de croissance (21) d'estimer le poids, la taille et le segment supérieur pour les examens manquants entre les âges de 3 mois et 3 ans, il n'en a pas été de même pour les plis cutanés qui n'ont été étudiés que sur la population des enfants effectivement présents (tableau 1).

(*) Travail effectué avec l'aide de la Direction générale de la Recherche scientifique et technique, contrat n° 71.7.30.96.

** Nous remercions les Editions Doin, Paris, qui ont donné l'autorisation de reproduire cet article paru dans «Archives Françaises de Pédiatrie» 1974, 31, 875-886.

TABLEAU 1. Effectifs présents aux différents examens aux âges de 3 mois à 3 ans

	Nombre total d'enfants	Nombre d'enfants présents aux examens faits à :						
		3 mois	6 mois	9 mois	1 an	18 mois	2 ans	3 ans
Garçons	163	123	140	130	142	133	119	113
Filles	133	105	108	100	110	106	100	96

RÉSULTATS

1. *Distribution*

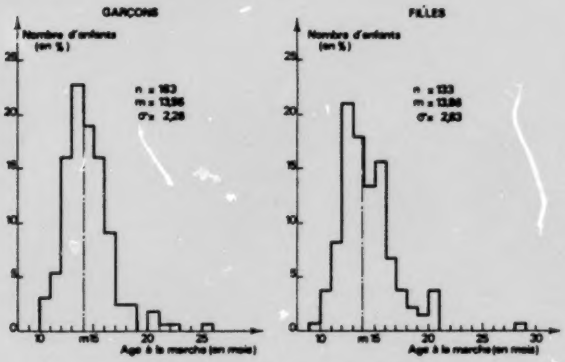

Fig. 1. Distribution de l'âge à la marche

Les figures 1 et 2 donnent la distribution et la distribution cumulée de l'âge du début de la marche. Les moyennes sont de 13,95 mois pour les garçons et 13,86 mois pour les filles, avec une dispersion assez forte (les valeurs s'étalent de 9 à 28 mois). La différence entre les sexes n'est évidemment pas significative.

La distribution apparaît légèrement dissymétrique, avec étalement vers les fortes valeurs, suggérant comme signalé par Hindley *et al.* (7) sur 5 échantillons d'enfants européens dont l'un représente en partie notre population, une distribution lognormale. Les calculs ultérieurs ont été effectués à la fois avec la valeur brute de l'âge de la marche et son logarithme. Les résultats ayant été identiques, seuls ceux avec la valeur brute sont présentés dans la suite.

D'autre part, les facteurs d'environnement pouvant avoir une influence différente sur les garçons et les filles, les deux sexes seront étudiés séparément, bien qu'ils soient strictement comparables du point de vue des valeurs moyennes.

2. *Relation avec l'état de santé.*

6 garçons et 6 filles ont marché à 20 mois ou plus. Un examen rétrospectif des dossiers de ces enfants attardés nous a permis de constater qu'au cours de leurs deux premières années, les 6 garçons avaient été atteints de troubles sérieux (3 rachitismes graves, 3 troubles digestifs et vomissements importants dont 2 associés à une hospitalisation pour otite bilatérale suivie de rhinopharyngites à répétition pour l'un, d'une hospitalisation de trois semaines par suite d'une rougeole pour l'autre) ainsi que 4 filles sur 6 (2 rachitismes graves, 1 anorexie, 1 otite avec complication entraînant 3 semaines d'hospitalisation). Pour les 2 autres filles on n'a rien trouvé de particulier.

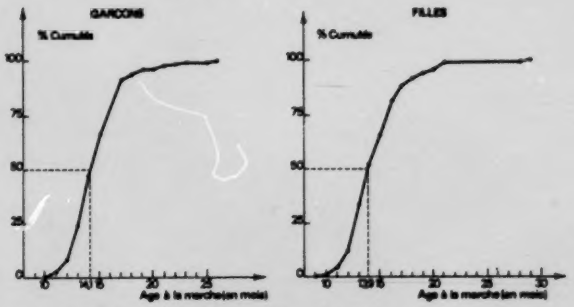

Fig. 2. Distribution cumulée de l'âge à la marche.

Il aurait sans doute été intéressant d'étudier de façon systématique l'influence de l'état de santé sur l'âge du début de la marche. Seul jusqu'à présent le rachitisme a été considéré ; 20 enfants (15 garçons et 5 filles) de l'échantillon ont souffert d'un rachitisme au cours des 2 premières années. Les âges moyens de la marche ont été pour ces enfants de 14,8 mois et 14,4 mois, sensiblement plus élevés, surtout chez les enfants, que dans le groupe total.

3. *Relations avec les conditions de la naissance.*

Aucune relation n'a été trouvée avec les conditions de l'accouchement et le poids de naissance. Pour le poids de naissance on note une faible corrélation négative à la limite de la signification chez les garçons. On observe également chez ces garçons une faible relation — à la limite de la signification — avec la saison de naissance : les enfants nés au cours de l'été marchent en moyenne plus tôt que les....

4. *Relations avec le niveau social.*

L'âge moyen à l'apparition de la marche des garçons de niveau social élevé (catégorie 1 et 2 de Graffar) est inférieur à ceux des autres niveaux (3-4 et 5), mais cette différence n'atteint pas le seuil de signification. Ces âges moyens sont respectivement 12,9, 14,0 et 14,1. Pour les filles, les moyennes sont 13,5, 13,9 et 13,9.

5. *Relations avec le développement psychomoteur et intellectuel* (tableau 2).

TABLEAU 2. Développement psychomoteur et intellectuel et âge à la marche

	Coefficient de corrélation r entre l'âge à la marche et :				
	Q.D. 2 ans	Q.D. 3 ans	Q.I. 5 ans	Q.I. 8 ans	Q.I. 10 ans
Filles	(97) – 0,37***	(103) – 0,41***	(104) – 0,23*	(72) – 0,20	(50) – 0,08
Garçons	(114) – 0,36***	(122) – 0,38***	(121) – 0,14	(84) – 0,22*	(48) – 0,31*

La signification est notée :
*si $p \leq 0,05$
** $p \leq 0,01$
*** $p \leq 0,001$
Les effectifs sont indiqués entre parenthèses.

Si la relation négative entre l'âge du début de la marche et le quotient de développement mesuré à 2 ans est tout à fait attendue, puisque le test effectué à cet âge comporte des épreuves de locomotion, les relations avec les quotients d'intelligence mesurés à des âges ultérieurs sont plus intéressantes : les enfants qui marchent tôt ont un quotient moyen plus élevé, même à l'âge de 10 ans (du moins pour les garçons).

On n'a par contre trouvé aucune relation nette avec la propreté tant diurne que nocturne.

6. *Relations avec le développement somatique.*

Les résultats concernant la taille et les deux segments, le poids et ses composantes grasse et maigre, les plis cutanés, l'indice de corpulence, figurent aux tableaux 3 A et 3 B.

Chez les garçons, on observe une relation négative avec la taille (surtout avec le segment supérieur) et le poids (surtout avec sa composante maigre); aucune relation n'est trouvée avec la quantité de graisse. A un développement squelettique et musculaire plus faible (estimé par la masse maigre) correspond donc un âge moyen plus élevé au moment des premiers pas.

Chez les filles, au contraire, on note une corrélation positive avec les plis cutanés, et des corrélations non significatives, mais de signe opposé avec les masses grasse et maigre, ce qui se traduit par une corrélation nulle avec le poids, mais positive avec le pourcentage de graisse. A une augmentation de la masse adipeuse correspond donc un retard de l'âge à la marche, retard d'autant plus important que la composition corporelle sera plus riche en graisse.

Le comportement différent des garçons et des filles apparaît très nettement sur les figures 3 et 4, qui comparent le pourcentage de graisse et la masse maigre des enfants avancés, moyens et en retard pour l'âge de la marche.

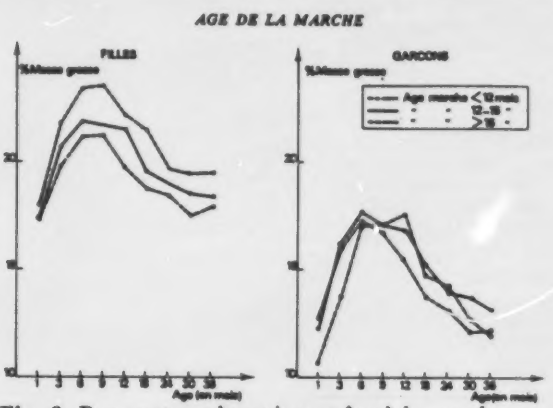

Fig. 3. Pourcentage de graisse et âge à la marche.

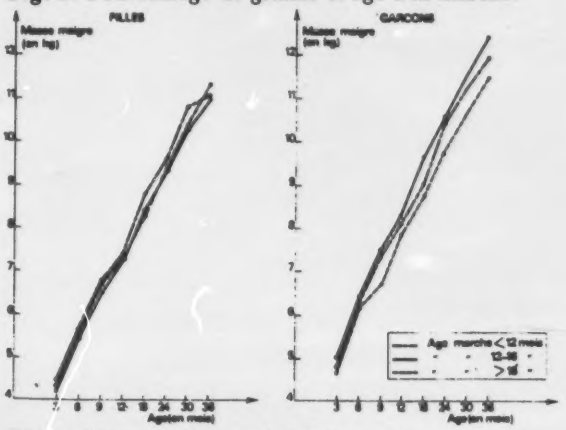

Fig. 4. Masse maigre et âge à la marche.

TABLEAU 3 A. Développement somatique et âge à la marche. Garçons (n = 163)

	Coefficient de corrélation r entre âge à la marche et mesures faites à:						
	3 mois	6 mois	9 mois	1 an	18 mois	2 ans	3 ans
Poids	−0,18*	−0,18*	−0,19*	−0,17*	−0,15	−0,15	−0,17
Taille	−0,22**	−0,25**	−0,21**	−0,20**	−0.23**	−0,24**	−0,16
Segment supérieur	−0,20**	−0,22**	−0,21**	−0,20**	−0,17*	−0,23**	−0,19*
Segment inférieur	−0,13	−0,15*	−0,11	−0,10	−0,18*	−0,16*	−0,08*
P.C. Biceps	−0,07	−0,01	0,14	0,18*	0,07	0,13	0.002
P.C. Triceps	−0,19*	−0,03	0,15	0,18*	0,12	0,12	0,02
P.C. sous-scapulaire	−0,07	0,04	0,02	0,07	0,07	0,01	−0,05
P.C. supra-iliaque	−0,17	−0,05	0,09	0,20	0	0,06	−0,05
% masse grasse	−0,17	0,03	0,13	0,22**	0,10	0,10	−0,02
Masse grasse	−0,15	−0,07	−0,04	0,07	−0,02	−0,04	−0,14
Masse maigre	−0,08	−0,18*	−0,24**	−0,20*	−0,15	−0,25**	−0,23*
Index de corpulence	−0,15	−0,13	−0,16*	−0,14	−0,09	−0,09	−0,14

TABLEAU 3 B. Développement somatique et âge à la marche. Filles (n = 133)

	Corrélation entre âge à la marche et mesures faites à:						
	3 mois	6 mois	9 mois	1 an	18 mois	2 ans	3 ans
Poids	−0,04	−0,05	−0,08	0,08	−0,08	−0,05	−0,01
Taille	0,01	−0,07	−0,08	−0,11	−0,16	−0,16	−0,11
Segment supérieur	0,03	−0,01	−0,02	−0,03	−0,13	−0,19*	−0,03
Segment inférieur	−0,02	−0,11	−0,12	−0,14	−0,14	−0,03	−0,15
P.C. Biceps	0,20*	0,13	0,40***	0,24*	0,19	0,10	0,17
P.C. Triceps	0,19	0,25**	0,28**	0,16	0,22*	0,26**	0,19
P.C. sous-scapulaire	0,15	−0,003	0,02	0,03	0,08	0,17	0,20
P.C. supra-iliaque	0,02	0,16	0,20	0,14	0,22*	0,04	−0,02
% masse grasse	0,15	0,15	0,26**	0,17	0,22*	0,20	0,20
Masse grasse	0,12	0,08	0,18	0,07	0,10	0,13	0,16
Masse maigre	−0,02	−0,14	−0,05	−0,16	−0,19	−0,01	−0,004
Index de corpulence	0,03	−0,05	−0,08	−0,07	−0,03	0,01	0,04

Pour les corrélations avec les plis cutanés et l'évaluation des masses grasse et maigre, les effectifs sont ceux donnés au Tableau 1. La signification est notée: * si $p \leq 0,05$; ** si $p \leq 0,01$; *** si $p \leq 0,001$.

7. *Relations avec l'âge d'apparition de la première dent.*

Une relation (significative pour les garçons) a été trouvée avec l'âge d'apparition de la 1re dent. Le groupe d'enfants dont la 1re dent est apparue entre 6 et 9 mois marche en moyenne 1 mois plus tôt que les groupes d'enfants ayant eu leur 1re dent soit avant 6 mois, soit après 9 mois.

DISCUSSION

Comme certaines études l'ont montré (11, 13, 17, 18), les mères interrogées sur l'âge du début de la marche de leur enfant longtemps après que les premiers pas ont eu lieu ont tendance à sous-estimer cet âge, d'où l'intérêt de l'étudier au cours d'enquêtes longitudinales. La nôtre n'est pas parfaite de ce point de vue, car certains enfants ont manqué à divers examens, de sorte que l'intervalle de temps premiers pas - interrogatoire a pu être plus long que prévu. Cependant, ce défaut paraît léger, car pour 87 % des enfants il a été de moins de 6 mois et pour 94 % de moins de 1 an. Pour 2 enfants seulement, il a dépassé 3 ans.

Les comparaisons fines entre les moyennes trouvées dans ce travail et celles de la littérature sont difficiles, du fait des possibles différences dans la définition des

premiers pas et du caractère rétrospectif de la plupart des études antérieures.

Dans la seule autre étude française, celle de Pineau (16), les âges sont de 13,37 pour les garçons et 13,07 pour les filles, inférieurs aux nôtres, mais les enfants avaient de 7 à 14 ans au moment de l'enquête. Les 7 échantillons de Smith *et al.* (23) s'échelonnaient de 12,21 mois à 14,07 pour les garçons et de 11,95 à 12,69 pour les filles, mais là encore il y a une possible sous-estimation. Parmi les enquêtes longitudinales, il convient de citer celle de Bayley (2), qui trouve pour l'ensemble des garçons et des filles une moyenne de 13,67, et surtout les autres enquêtes européennes cordonnées par le Centre international de l'Enfance (7). L'échantillon parisien est celui qui marche le plus tard, les échantillons suédois et belge le plus tôt (respectivement 12,51 et 12,65 mois). Il est possible que cet écart soit dû à une différence dans la définition de premiers pas adoptée par les divers enquêteurs; il paraît cependant suffisamment important pour pouvoir être considéré comme réel, d'autant plus que les enfants des échantillons belges et suédois sont de poids et tailles supérieurs à ceux de notre échantillon.

La quasi-totalité des enquêtes, comme la nôtre, ne mettent pas en évidence de différences significatives entre les sexes [bien que Hutt (9) semble admettre comme évidente l'avance des filles]. Seule l'étude de Smith *et al.* (23), réanalysée par Hindley (8), montre au contraire une différence très significative. A partir d'une hypothèse de Graffar et Corbier (6), Hindley *et al.* (7) suggèrent comme cause possible du désaccord le fait que les garçons tendent à être plus sensibles que les filles aux facteurs d'environnement.

Les données de la littérature concernant le développement somatique sont rares et peu nettes; de plus, dans la plupart des travaux, les sexes ne sont pas étudiés séparément. On admet généralement que les enfants minces et allongés marchent plus tôt que les enfants lourds, mais cette conclusion résulte apparemment plus d'une impression que de résultats solidement établis.

En ce qui concerne la taille, Norval (4) trouve une corrélation négative entre l'âge du début de la marche et la taille à la naissance; Bayley (2), en accord avec les résultats de Shirley (20), observe une corrélation positive avec le rapport segment supérieur à la taille totale, entre les âges de 12 à 18 mois, ce qui indiquerait que les enfants aux longues jambes marchent plus tôt que les autres.

Pour le poids, Pineau (16) trouve une corrélation négative significative avec le poids à la naissance chez les garçons*; chez les filles, la relation, bien que de même sens, n'est pas significative. Il en est de même dans l'échantillon de Norval (14). Par contre, Peatman et Higgons (15) ne trouvent aucune association avec le poids au moment du début de la marche et Bayley (2) avec l'indice de Quetelet.

A notre connaissance, enfin, il n'existe pas d'étude sur les relations entre l'âge du début de la marche et l'épaisseur du tissu adipeux.

Il est possible que certaines des contradictions signalées ou le manque de netteté des résultats s'expliquent par une différence entre les garçons et les filles: nous avons trouvé que les garçons en retard sont plus petits et légers, leur masse maigre diminuée indiquant sans doute un retard musculaire et osseux; les filles retardées, au contraire, sont celles dont la masse adipeuse est relativement la plus importante. On conçoit que le mélange des 2 groupes conduise à des associations très affaiblies. De même, il n'est pas étonnant de ne trouver aucune relation avec l'indice $\frac{P}{T^2}$, qui ne sépare par les composantes maigre et grasse du poids.

Il est certain que les estimations de ces dernières quantités que nous avons utilisées sont terriblement sujettes à caution. Ce n'est pas ici le lieu de discuter en détail de leur bien-fondé. Disons simplement que les valeurs qu'elles fournissent sont du même ordre que celles obtenues plus directement (5), du moins à partir de 8 ans (on ne dispose pas de données comparatives avant cet âge).

De toute façon, l'épaisseur du tissu adipeux, mesurée par les plis cutanés, est associée positivement chez les filles à l'âge du début de la marche; aucune relation n'étant retrouvée chez les garçons. Nous pensons donc que, même si les moyennes de pourcentage de graisse que nous présentons sont discutables, le phénomène influence différente de la quantité de graisse sur l'âge de la marche selon le sexe est un phénomène réel.

Il resterait bien entendu à interpréter cette différence qui apparaît dès la naissance.

La relation négative avec le quotient intellectuel jusqu'à un âge avancé est intéressante: elle semble indiquer qu'un âge de la marche précoce est un indice d'un bon développement intellectuel.

La relation curieuse avec l'âge de la première dent nécessiterait d'être reconfirmée: elle n'est en effet pas en parfait accord avec les résultats de Pineau (16) et Aubenque (1), qui notent une corrélation positive, du moins chez les garçons.

L'effet de la saison de naissance, difficile à expliquer, mériterait aussi d'être reconfirmé. Des études récentes de Marshall (12) et Jeurissen (10) signalent en effet un phénomène analogue d'influence des saisons sur la croissance en taille et l'âge des premières règles.

En ce qui concerne le niveau social, nos observations sont à rapprocher de celles de Sand (19), qui, dans son étude d'un groupe d'enfants bruxellois, n'observe pas de corrélation significative du quotient de développement avec le niveau social à la naissance, mais avec le niveau social à 18 mois et plus.

RÉSUMÉ

L'âge de la marche a été étudié chez 163 garçons et 133 filles suivis régulièrement depuis la naissance. Il n'est pas différent selon le sexe (moyenne de 13,98 chez le garçon et de 13,85 chez la fille).

Nos résultats indiquent que l'âge à l'apparition de la marche, phénomène lié à la maturation neurologique et musculaire, varie avec d'autres critères de maturation biologique et intellectuelle. Nous avons ainsi été intéressés de constater que la précocité de la marche a été chez ces enfants l'indice d'un bon développement intellectuel ultérieur. Nous retiendrons aussi le fait que le retard de la marche est lié chez le garçon à une diminution de la masse maigre, donc à un faible développement squelettique et musculaire, alors que chez la fille, dont la composition corporelle est plus riche en graisse, il est lié à l'augmentation de la masse adipeuse.

SUMMARY

The age of onset of walking has been studied among 163 boys and 133 girls regulary followed after birth. There is no significant difference in the means for the sexes (13.98 for boys and 13.85 for girls).

Our results show that the age of first walking, which is related to neurological and muscular maturation, varies with other criteria of biological and intellectual maturation. Thus it appears that precocity of walking is an indication for a good later intellectual development. Further, for the boys, lateness of walking is related to a lower lean body mass, and hence with a lower skeletal and muscular development, while, for girls, for whom the proportion of body fat is higher, lateness is related to a higher proportion of body fat.

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Trends in Development of Abilities Related to Somatic Growth[1]*

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The development of abilities has been shown to follow divergent trends. A good illustration of this phenomenon is found in TANNER [1964]. Using data from various studies, he illustrates different individual trends in ability development. HINDLEY [1962] and KLACKENBERG-LARSSON and STENSSON [1968] found diverging trends in the development of abilities when related to socio-economic status.

Ability also seems to be connected to somatic status. In a survey of earlier investigations, HUSÉN [1951] found that the correlation between somatic measures and intelligence were mostly around + 0.20 and did not exceed + 0.30. The reason for a positive correlation could be one of the following: '(1) The correlations may depend on similarities in rate of growth. (2) Social handicap or social advantages may influence mental and somatic development simultaneously. (3) A common biological factor termed "common vitality" may further both somatic and mental development' [HUSÉN, 1951, p. 46].

The main aim of this study is to investigate trends in the development of abilities and to relate them to somatic growth. An examination of earlier research on the relationship between intelligence and somatic measures, and between ability development and socio-economic status, led us to formulate the following hypothesis: trends in the development of abilities are expected to be positively related to trends in somatic growth; (a) individuals with a faster rate of ability development than the population average have a more rapid rate of somatic growth; (b) individuals whose ability development proceeds at a slower rate than the population average have a slower rate of somatic growth.

METHODS AND PROCEDURES

This study is a part of a Swedish longitudinal project with a sample of 202 children studied from birth [KARLBERG *et al.*, 1968]. Intelligence tests were administered at 3, 6, 12, 18 and 24 months, and at 3, 5 and 8 years. From 3 to 24 months. Brunet-Lézine's psychomotor development test [BRUNET and LÉZINE, 1951] was used, and at ages 3, 5 and 8 years, the children were tested by a standardized Swedish version of the Terman-Merrill intelligence test [HELLSTRÖM, 1960; TERMAN and MERRILL, 1937].

The somatic measures selected were height and weight. These were recorded at birth and at 1, 3, 6, 9, 12, 18 and 24 months. From the age of 3 years on, somatic measurements were obtained every year [KARLBERG *et al.*, 1968a].

Subjects

To find the two groups needed for this study, Spearman's rank correlation was calculated between test occasion and IQ for every child. Rho is thus a measure of the course of ability development. Only children tested on eight or nine occasions have been included, i.e., 185 children, 113 boys and 72 girls.

If the children were to follow the average development of abilities, they would have roughly the same IQ on each measurement occasion and the rank correlation between the test occasions and the results from mental tests would be zero. The higher the rho, the more marked the increase from measurement to measurement. The more negative a coefficient, the more marked a decrease compared to the average. Rank correlations only show the continuity of increase or decrease of IQs and not the size of this increase or decrease. The more consistent the increase or decrease is over eight or nine occasions, the more firmly it can be stated that there is a faster or slower ability development compared with the population average.

The levels of significance 0.05 of rhos gives the limits at n = 8, rho = ± 0.64 and n = 9, rho = ± 0.60. A cut-off was drawn at rho = ± 0.64. Thus, all 36 children with rho higher than + 0.64 and all children with rho lower than − 0.64 have been selected. Those with a coefficient higher than + 0.64 will be referred to as the rapid group, R, and those individuals that have a coefficient lower than − 0.64 will be called the slow group, S. Both groups happened to consist of 25 boys and 11 girls.

Analysis

The somatic measurements have been transformed into standard scores with mean = 0 and standard

[1] We are most grateful to Dr. YVONNE WAERN from The Psychological Laboratories, University of Stockholm, for her statistical advice, and to Prof. C. B. HINDLEY, Institute of Education, University of London, who read the manuscript and made valuable suggestions.

This study has been financed by Magn. Bergwalls Stiftelse and the City Board of Education, Stockholm.

* We acknowledge the authorization given by S. KARGER AG, BASEL, to reproduce this paper appeared in Human Develop., 1974, 17, 152-159.

deviation = 1. To avoid negative values, the constant 3 has been added to every score. To study the relationship between the development of abilities and somatic development, an analysis of variance was performed according to the following design: columns were measurement occasions and rows were children and groups. Two F quotients have been calculated, one testing group effects and the other testing interaction effects between groups and occasions. The analysis was carried out in two stages. The hypotheses tested in each stage were: (1) the developmental curves of somatic measures do not deviate significantly from the horizontal line; (2) the somatic development of groups R and S do not differ significantly from each other. This is a reformulation of the previously stated hypotheses, adapted to the analysis of variance. As the measures are correlated, WINER'S [1962, p. 298] method for repeated measurements has been used. Because the children in group R and group S are the same on the different measurement occasions, the effect of memberships to a group is nested to differences between individuals.

According to the hypothesis, there should be a rising trend in the somatic curve of group R and a falling trend in the curve of group S. When there was a significant deviation from a horizontal line of the somatic curves, a trend analysis for testing linear, quadratic or cubic trends was carried out [HAYS, 1963, p. 539]. As the intervals on the scale have to be equal in a trend analysis, the age intervals 4 weeks to 2 years and 2-8 years were treated separately. The analysis of variance was performed for the entire age range 4 weeks to 8 years and for the two shorter intervals. All calculations have been done separately for boys and girls.

RESULTS

Figures 1 and 2 show that for the boys the hypothesis seems to be confirmed. The analysis of variance when testing the first hypothesis showed that weight development for boys in both group R and group S deviates from a horizontal line during the whole period (group R: $F = 6.53$, $df = 10/240$, $p < 0.01$); group S: $F = 4.26$, $df = 10/240$; $p < 0.01$). When the period is divided into two parts, no significant deviations are found between 2 and 8 years. The development of height also deviates significantly if the whole period is taken into account (group R: $F = 5.68$, $df = 10/240$, $p < 0.01$; group S: $F = 3.95$, $df = 10/240$; $p < 0.01$). When the period is divided up, only group S deviates significantly

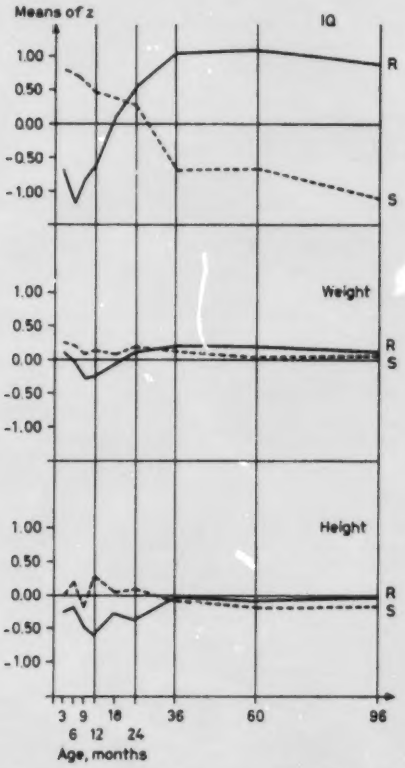

Fig. 1. Means of standard scores, z for IQs, weight and height of group R and group S (males).

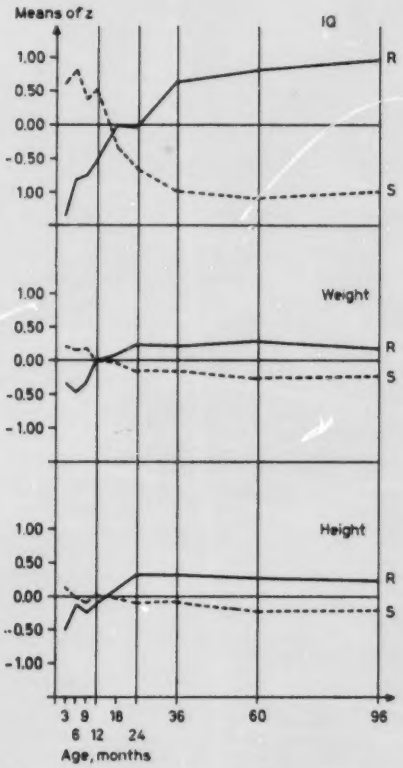

Fig. 2. Means of standard scores, z for IQs, weight and height of group R and S (females).

between 4 weeks and 2 years ($F = 2.86$, $df = 4/96$, $p < 0.05$). The somatic development curves for the girls do not at any time show a significant deviation from a horizontal line.

When tested for interaction, the somatic development of boys shows significant F quotients during the whole period (weight: $F = 9.21$, $df = 25/480$, $p < 0.01$; height: $F = 9.38$, $df = 25/480$, $p < 0.01$), and during the period 4 weeks to 2 years (weight: $F = 9.21$, $df = 4/192$, $p < 0.01$; height: $F = 8.09$, $df = 4/192$, $p < 0.01$). The girls show a significant interaction in height between the groups during the whole period 4 weeks to 8 years ($F = 2.87$, $df = 10/200$, $p < 0.01$) and during the period 2-8 years ($F = 3.67$, $df = 6/120$, $p < 0.01$).

When a significant deviation from a horizontal line appeared, a trend analysis of the deviation was undertaken. This showed that in every case the deviations were linear (group R weight: $F = 24.73$, height: $F = 21.58$; group S weight: $F = 10.64$, height: $F = 8.11$). Thus, the rate of change of the somatic measures, increase in group R and decrease in group S, are constant compared to the average development.

DISCUSSION

Trends in Mental Development

Two groups were selected for the study. One group (group R) had a mean of 84 DQ at 3 months of age and 114 IQ at 8 years of age. The other group (group S) had a mean of 111 DQ at 3 months of age and 84 IQ at 8 years of age.

Over a period of 8 years, a mean change in IQ of about 30 points was observed for both groups. The calculation of rank correlations show the continuity of the increase or decrease but not the size of it. The two groups investigated differ from the population average in mental development. With respect to mental age, group R consistently shows a larger than average increase, and group S consistently shows a smaller than average increase. The curves of development cross at 18 months. Before that point, group S has a higher mean DQ than group R.

Possibly, there is a displacement of time in the development of the groups in relation to an average development, so that group S, at some stage during the time between conception and the first mental testing at 3 months, passes through a phase of more rapid development after which it returns to the average, i.e. relatively seen it decreases, giving the trend shown here. Group R should then at some time during the same period have had a relatively slower developmental phase, but, as a result of conditioning or quite spontaneously returned to the average rate of development. During this period, the development is so rapid that even a displacement of a period as short as 1 week would cause quite a large difference at 3 months.

Another possible explanation for the large initial differences between the R and S groups and their resulting development could be that the two groups vary in their mental factor structure. Group S could, for example, be better developed motorically than verbally, whereas the opposite may be true for group R. In an investigation of African children [GEBER, 1962] it was found that when tested by Gesell's infant test, the children were more advanced in their psychomotor behaviour than the group on which the test is standardized. They kept this advantage up to the age of 18-20 months after which they decelerated. The older one is, the more culture-bound the tests are; this could be one explanation for a retardation. It is also possible that the ability structure of group S is not stimulated by its environment, while the opposite holds for group R.

The early measures of intelligence may be influenced by the individuals' activity level. Less active children may seem to demonstrate less intelligent behaviour at this stage. This would account for the very low initial values of group R. ESCALONA [1968] reports that children who show a lower degree of general activity at a very early stage, between 4 and 12 weeks of age, have a higher degree of oral activity which is bound to the feeding situation and that they practice their visual attention to a larger extent. Thus, a lower degree of activity facilitates a more intelligent future behaviour. It is difficult to conclude which one of the interpretations is the most convincing from the data presented here. The last mentioned seems to be most acceptable to us.

Relationships between Mental Development and Somatic Growth

The analysis of variance confirmed the hypotheses for boys. For girls, they were only confirmed for height and only to the extent that there is a group interaction in somatic development. This can be seen from figure 2 where the intersection between the height curves of group R and S occurs late (at about 3 years). This seem to be caused by the interaction effect during the period 2-8 years. Group R and group S seem to show the same differences in height development as they do in mental development. There seems to be a relationship between mental development and somatic growth among boys up to the age of 2 years. This relationship is less clear between 2 and 8 years of alge, although it is significant for the total period from 4 weeks to 8 years. The relationship between mental development and somatic growth suggests that the development of infants is due to some common factors, i.e. if the mental development is more rapid than average it is most likely that the somatic development shows the same trend and vice versa [cf. HUSÉN, 1951].

SUMMARY

From a longitudinal sample of 202 children studied from birth to 8 years of age, two extreme groups were selected. One group had a more rapid development than normal and the other a slower development when tested with Brunet-Lézine and Termann-Merrill tests. From the first measurements oc-

casion at the age of 3 months to the last one at the age of 8 years, the rapid group's mean change of ability was from 84 DQ to 114 IQ and the slow group's mean change from 111 DQ to 84 IQ. These groups were then compared with regard to development of weight and height. A relationship between the development of abilities and weight and height increases was found for boys aged 4 weeks to 2 years and between the development of abilities and height increase for girls aged 2-8 years.

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The somatic development of children in a Swedish urban community. A prospective longitudinal study.

I. Physical growth from birth to 16 years and longitudinal outcome of the study during the same age period *

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INTRODUCTION

Growth may be regarded as the resultant — the total outcome - of various biological processes. It is often discussed in terms of three dimensions — size, maturity and time. The process of growth and development begins at conception and ends at the attainment of the adult state. This may seem a trivial statement, but it has important implications for the analysis of growth in all three dimensions mentioned above.

As regards time, for example, growth and development in infants cannot be analyzed without consideration of gestational age, i.e. it is neccessary to use conceptional age instead of chronological age (birth age). But even at later ages the use of conceptional age or a transformation of it can give a better description of growth and development. A logarithmic conceptional age has been used in the analysis of dental development (20.25), pubertal development (16), skeletal development (23) and psycho-motor development (15). In another approach a conception-corrected chronological age has been used to analyse relative (percentage) differences between sexes and various populations in the ossification of the skeleton (11).

As regards size each individual aims, in principle, at his or her own preprogrammed adult level. At conception this level is set by genetic factors. However, this predetermined growth pattern may be modified by various environmental factors. This interplay is a fundamental part of the process leading to variations in adult size. The different levels of the individually predetermined growth pattern explain why various *"size ages"* (height age, weight age etc.) are not useful. A child having a height less than the mean for its age may be bound to end up as a relatively small adult, thus having an appropriate height for its age in consideration of the genetically predetermined growth pattern.

Maturation is a third aspect of growth. The evaluation of maturity is difficult, as no continuous scale of measurement is available, but a number of maturity criteria which can be used. If adhering strictly to the theoretical definition of the process of maturation only criteria will be used, that are criteria present in all individuals who have attained a certain level of maturity. Accordingly, the adult level of maturity will be the samed in all individuals. The eveluation of the maturity of a child is complicated by the fact that the child can only be examined at certain intervals. Thus, in practice, it is very rare that the age at attaining various maturity criteria can be exactly determined in individual children. However, there are exceptions — age at menarche in girls being the most important.

Growth and development are continuous processes but, as stated above, observations in individual children can usually only be made at certain intervals. This will effect the interpretation of the observations or measurements in different ways, depending on whether they are assessed by a variable with a continuous scale of measurement or by a variable with a discrete scale of measurement. When a continuous scale of measurement is used as is the case, for example, for standing height, the measurement made on a certain occasion may be taken to represent the present state of growth. On the other hand, when a variable with discrete stages in the scale of measurement is used (e.g. number of erupted teeth or puberty ratings), the observation does not present the present state of growth. In such a case it can only be concluded that the child is *within* a certain stage of development, which has been attained at an earlier age.

Information on the growth and development of children may be obtained in two ways. Either different children of varying ages are examined (cross-sectional approach) or the same children are observed at more than one age (longitudinal approach). A comprehensive review of the merits of each approach has been given by Tanner, (29). Suffice it to say that longitudinal data are necessary, for example, when analysing increments of body measurements and/or individual growth patterns of when correlating various maturational events. On the other hand cross-sectional data may be more suitable when for example, the only aim is to establish standards of distance values of body measurement (height attained at a certain age etc.), since sufficient data can be collected in a less expensive and less time-consuming way.

In this paper longitudinally collected data on physical growth will be presented. A detailed report is also given on the group of children investigated, with special reference to the longitudinal outcome of the study.

* We acknowledge the authorization given by the Editor of Acta Pediatrica Scandinavica to reproduce this paper appeared in Acta Ped. Scand., 1976, Suppl. 258, 7-31 (-76).

DESIGN OF THE STUDY

Material

Data on somatic development have been collected for 212 children (122 boys and 90 girls) as part of a prospective longitudinal and interdisciplinary study of growth and development in children in a Swedish urban community (18). The study began in 1955 and is still going on. The study is co-ordinated with four other European longitudinal growth studies (in Brussels, London, Paris and Zürich) by the International Children's Centre in Paris (10). One hundred and eighty-three of the 212 children were recruited antenatally by asking every fourth pregnant woman at the only antenatal clinic of the community chosen for the study. More than 90% of the pregnant women were controlled at the antenatal clinic. The other 29 children constitued a pilot group and were the first children selected for the study. In these cases the selection was made either antenatally (8 cases) or neonatally (21 cases) all of the children being born at the only maternity unit of the community. The 212 children were born between April 1955 and March 1958.

The representativeness of the sample has been discussed in an earlier report (18). Regarding socio-economic factors suffice it to say that at birth the sample were representative for contemporary Swedish urban children, with 17% in the upper social stratum, 37% in the middle stratum and 46% in the lower stratum according to the customary Swedish classification of social classes bases mainly on the father's occupation. At sixteen years, 170 children (84.%) were still being followed in the study. From birth to 16 years 127 (70.9%) of the 179 children belonged to the same social class, while 52 children had changed social class once or more. Of the latter group 32 children had changed to a higher social class and 9 children to a lower one. Eleven children had changed social class more than once and in both directions.

Analysis of various perinatal factors has shown good agreement between the present study and a nationwide investigation of all live-born new-born infants in Sweden during the period July 1956 to June 1957 (8). A comparison at later ages with other investigations of growth in contemporary Swedish children will be presented below (see Discussion).

Examination

The children have been examined at the following ages: 1 month (4 weeks), 3 months (13 weeks), 6 months (26 weeks), 9 months (39 weeks), 12 months (18 months, 2 years and subsequently once a year. The examination comprised somatic, psychological and social investigations. From the age of ten years certain body measurements (weight, standing height and sitting height) have been taken every third month, but only measurements taken at even ages (10.0, 11.0 etc.) are included in this report. Furthermore, this report will only comprise measurements up to the age of 16 years. In order that the investigation may be considered to represent true ages the following tolerances as regards time have been aimed at: for the age of 4 weeks ± 2 days; for 3-18 months ± 1 week; for 2-3 years ± 2 weeks and subsequently − 2 weeks and + 3 weeks.

In the various analyses and editorial procedures (see below) chronological age has been calculated as decimal age (32).

Methods of measurement

Body measurements have been taken according to a standardized programme recommended by the International Children's Centre in Paris (10).

Weight — nude weighing, up to 15 kg with an accuracy of 0.01 kg and thereafter with an accuracy of 0.1 kg.

Recumbent length and crown-rump length, measured with the child lying supine on a special table fitted with a measuring tape and sliding footboard; the measurements were made with an accuracy of 0.1 cm.

Standing height and sitting height, measured with a "streching upward" technique according to Tanner et al. (33)

Femur bicondylar and humeru bicondylar widths measured with the knee and the elbow, respectively, flexed at 90°; biacromial and *pelvic widths* measured between the most lateral points of the acromion and the iliac crest, respectively; *thorax depth* and *thorax width* measured at the level of the mamilla at mid-respiration; special metal calipers graded in mm were used.

Head circumference and chest circumference, the latter measured at the level of the mamilla at mid-respiration; *upper-arm* and *calf circumference* recorded as maximum circumferences at passive flexion of the elbow and the knee, respectively; a narrow (6 mm) metal tape graded in mm was used with firm tension applied when measuring head circumference (maximum occipito-frontal circumference) but only a rather loose adaptation to the Skin when taking the other circumference measurements.

Subcutaneous tissue measured at four sites, over the *biceps*. A skinfold was lifted and its thickness was measured with the Harpenden Skinfold Calipers (Edwards et al. (7) graded in 0.2 mm. The mean of three measurements was used.

Anterior fontanel measured as the shortest distance between parallel bone edges with a narrow metal tape graded in mm.

For further details see Falkner (10). The measurements have been made on the right side of the body.

About 80% of the measurements were made in the morning between 8 and 10 a.m. Two examiners (H.L. and I.S.) made over 90% of the measurements.

EDITORIAL PROCEDURES

Erroneous values

About 66,000 values of measurements have been collected up to the of 16 years (Table 1). Two types of erroneous values may have been registered, viz. errors of

measurement and errors of an administrative character (e.g. when filling in the forms or punching the data cards). In order to detect erroneous values tow approaches have been used. By means of a computer programme scatter plots of all body measurements against age have been individually for all children thus giving a graphic representation of the individual growth curves. Values not lying within the smoothed pathway of the obtained values have been checked on the original data records. The other approach has been to check values lying outside ± 2 standard deviations of the various body measurements analysed as distance values at each age. In order to detect erroneous values within the range of ± 2 standard deviations the same approach has also been used for increment values.

In 329 measurements (0.5 % of the measurements) an administrative fault has been detected. These values have been corrected. In about 300-500 other measurements highly questionable values have been registered. After having scrutinized each of these values with consideration to possible errors of measurement and the overall pattern of growth (i.e. looking at the growth curve of all body measurements in each individual), we have decided to exclude 122 of the values (0.2% of the measurements). It is of interest that more than half of these measurements had been made by another person than the two chief examiners and that half of them concerned children less than 4 years of age. The number of values excluded for each body measurement is specified in Table 1. Biacromial width and sitting height were the body measurements with the highest number of eliminated values. We have been very restrictive in excluding values, especially for skinfold, and have only done this for values grossly deviating from the individual trend of growth pattern.

Another indication of the necessity — and potential benefit — of a general overhaul in a study like this is that when going through the original records 24 forms (0.5%) registered as missing in the computer lists were rediscovered.

TABLE 1
Body measurements included in the present study.
Number of measurements excluded because
a questionable value had been recorded

Body measurement	No of measurements included	excluded	Body measurement	No of measurements included	excluded
Weight	4.072	0	Thorax width	1.194	3
Supine length	2.369	0	Thorax depth	1.194	5
Crown-rump length	2.366	8	Chest circumference	3.606	8
Standing height	2.636	0	Upper arm circumference	4.054	8
Sitting height	2.611	19	Calf circumference	4.052	6
Biacromial width	4.049	22	Biceps skinfold	4.047	1
Pelvic width	4.050	10	Triceps skinfold	4.045	2
Femur bicondylar width	4.054	6	Subscapular skinfold	4.042	0
Humerus bidoncylar width	4.054	0	Supra-iliac skinfold	4.040	3
Head circumference	4.051	4	Anterior fontanel	1.596	10

Departures from the longitudinal design

As in all longitudinal investigation, there have been inevitable departures from the design presented above. Three kinds of such departures will be discussed:

1. Not all children remain in the study during the whole period of investigation; children developing an abnormal growth pattern and thus not qualified to belong to the reference population will also be discussed in this group.
2. The children remaining in the study are not examined at every age.
3. Not all examinations are done within the tolerance limits of the target ages.

At sixteen years 179 (84.4%) of the original 212 children were still being regularly followed. Eighteen boys and fifteen girls have left the study at various ages (Fig. 1). At lower ages the most frequent reason for leaving the study was that the family moved abroad or to distant parts of Sweden. If the family moved when the children were older the children usually remained in the study and visited the centre once a year together with their father and/or mother.

Eighteen children living relatively far away (more than 200 km from the centre) have remained in the study. At 16 years only 81/179 children were living in the same town as at birth.

One boy developed a cranial synostosis with mental retardation and has not been examined after the first year. One boy was killed in a traffic accident at the age of six years. Lack of interest in continuing in the study

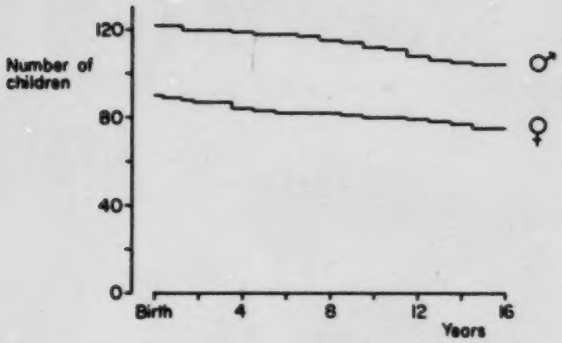

Fig. 1 Number of children remaining in the study at each age.

was considered to be the main reason in all cases in which the child dropped out of the study between 8 and 16 years. The reasons for not remaining in the study are summarized in Table 2.

TABLE 2
Reasons why certain children left the study, according to parent's statement.

Moved abroad or to other parts of Sweden	7
Killed in accident	1
Mental retardation	1
Lack of interest	24

An analysis of the socioeconomic background of the children lost to follow-up has shown some differences in comparison with the total sample. More of the lost children, especially among the girls, belonged to the upper social class (Table 3). Change of domicile was considered to be the main reason for leaving the study in 4/8 children in the upper social class but only in 3/35 children in the other two social classes.

TABLE 3
Socioeconomic classification of children who left the study.

Social class	No of children lost BOYS	GIRLS	Percentage of children lost
1	3	5	22.9
2	10	4	16.9
3	5	6	11.7

Children lost to follow-up

Although the number of children lost to follow-up is relatively small in the present study in comparison with other longitudinal studies, it is essential how the losses have influenced the results. Is has been possible to obtain information from school health records for 25/33 of the lost children. For these 25 children data on general health and body size (weight and standing height) are thus available from the age of seven to at least 16 years, the period of compulsory education in Sweden. For various reasons the somatic development after leaving the study is unknown for eight children.

TABLE 4
Some data on children who left the study and for whom nothing is known about subsequent somatic development.

Sex	Social class	Age as last examination	Reason for leaving the study
G	3	3 months	lack of interest
G	1	12 months	moved abroad
B	3	12 months	craniosynostosis + mental retardation
G	3	5 years	moved abroad
B	3	6 years	killed in accident
B	2	12 years	lack of interest
B	2	12 years	lack of interest
G	3	13 years	lack of interest

We have investigated the possibility of a difference in body size between children lost to follow-up and those remaining for study in two ways. One has been to compare the body measurements of the two groups of children, while the children later lost to follow-up still participated in the study. No consistent statistical differences have been found. A difference corresponding to $p < 0.05$ in a t-test has been found at isolated ages only (*in boys:* at 3 months for pelvic width, at 12 months for biceps skinfold, at 3 years for subscapular skinfold, at 6 and 7 years for supine length and at 10 years for standing height; *in girls:* at 3 months for anterior fontanel).

In the other method the data from the school health records of the children lost to follow-up are used. However, it should be emphasized that the school measurements were taken by different examiners in a non-standardized way. Assuming that all children had remained in the study and that the same values of height and weight as in the school health records had been found, the mean values of height would have increased by 0.2-0.3 cm in girls and decreased by 0.1-0.2 cm in boys. Mean weight would not have changed in girls but would have decreased by 0.4-0.5 kg from the age of thirteen in boys. These differences are relatively

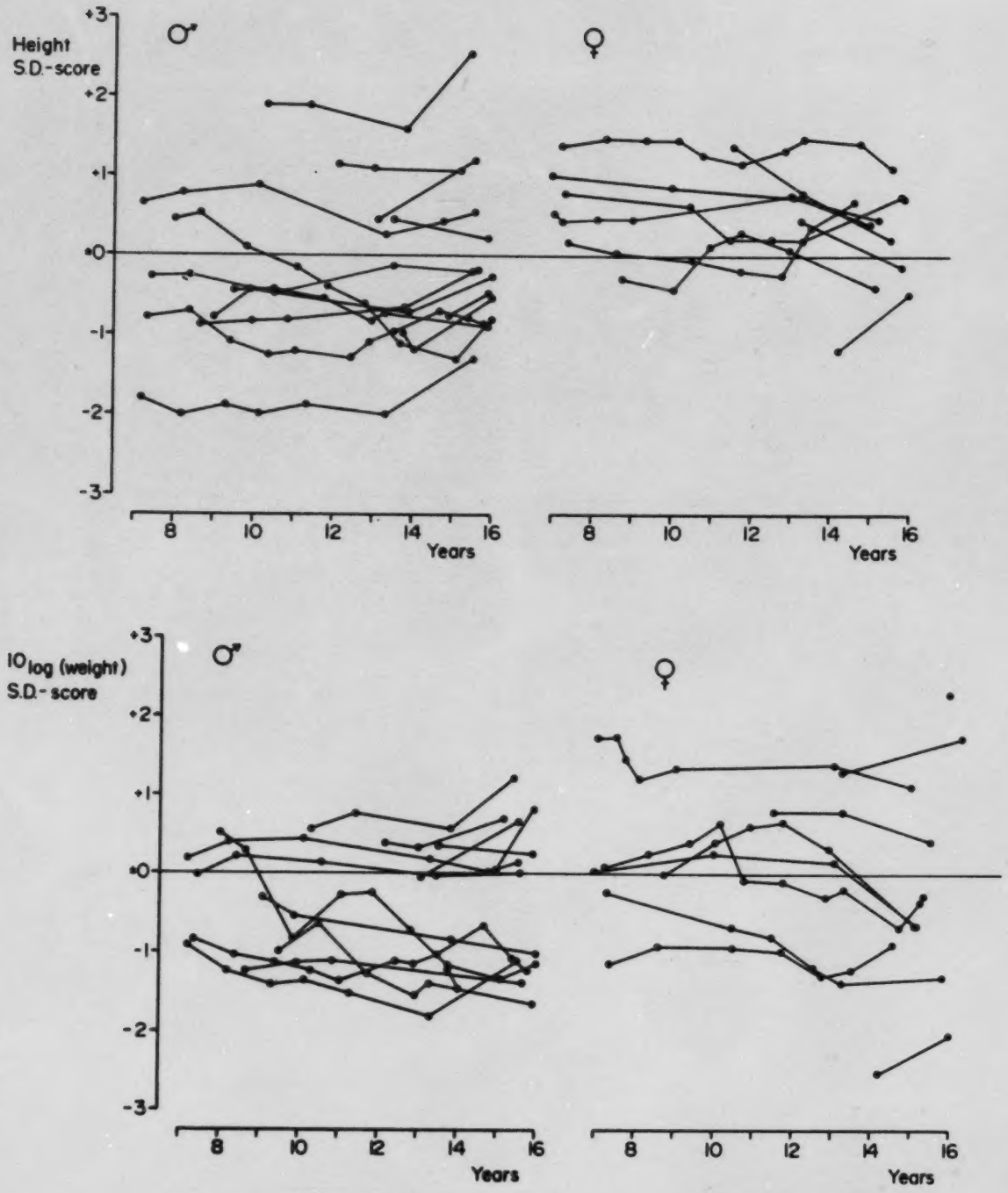

Fig. 2 Height and weight of the lost children after having left the study. (Expressed in standard deviation scores of the reference values) (Table 6a).

small and not statistically significant. In most cases the change of the mean value is less than half of the standard error of the mean.

In fig. 2 the individual values of height and weight taken from the school health records of the children lost to follow-up have been plotted as the corresponding standard deviation score at each age. More of the measurements of standing height in the girls were above the mean than below. The weights of the girls were more evenly distributed around the mean value. In the boys both standing height and weight were rather evenly distributed around the mean.

Children excluded for medical reasons

The state of health of the children has been assessed. By means of a questionnaire, a detailed appraisal of the child's state of health since the last visit has been performed each year. The present state of health has also been evaluated each year in a comprehensive and structured clinical examination.

Only conditions, which are not consistent with a normal growth pattern or which may have changed a normal pattern, have been sought. The growth and development of children with such arbitrarily chosen conditions have been analysed by comparing the individual growth curves for the various body measurements with the growth pattern of the total group. A definitely deviating growth pattern was found in only three cases. In a boy with cranial synostosis and mental retardation head circumference did not increase between the age of 6 and 9 months. At sixteen years two obese children had a weight that was roughly twice that of the mean for their sex. The boy weighed 111.9 kg and the girl 99.0 kg, while the second highest weight for boys was 79.6 kg and for girls 77.6 kg. The obese boy has had the maximum weight for his sex since the age of three and the obese girl since the same age with the exception of a temporary relapse between 12 and 14 years.

In two girls with surgically corrected congenital heart disease, there had been neither any sign of decelerated growth before the operation nor of catch-up growth after the operation. However, it should be stressed that both cases have been considered asymptomatic from a clinical point of view.

In a girl with recurrent urinary tract infections, leading to renal scarring, the adult height will be just above − 1 S.D. (at 17 years her standing height was 158.5 cm), which is somewhat lower than her relative position during childhood (between − and ± 0.0 in SD − score). However, since the height of both her parents was less than the mean for their sex (SD-score of mid-parent height is − 0.5 SD), there are no definite indications that the urinary tract infections have altered the growth pattern of the girl.

The school health records or 25/33 of the lost children have been searched for similar information on health and disease. There were only annotations of minor illnesses and accidents except for one boy. This child, who had been examined in the present study until the age of seven, when the family moved to another part of Sweden, had developed diabetes mellitus about three years after the last examination. Up to that age there was no indication of growth disturbance.

It is often said that normative standards of growth should be representative of "normal and healthy" children, thus implying that children who are not "healthy and normal" should not be included in the standardising group. However, there is no practical definition of which criteria should be used in such a selection. A certain degree of illness is characteristic of eleven a "healthy" child population. Nutritional and psychological factors must also be considered when discussing possible causes of growth disturbances. On the other hand, even when having a disease or abnormality an individual may follow the "normal" and genetically predetermined growth pattern. Accordingly, we have decided not to exclude from the group of children from which reference values of body measurements will be calculated all children with a classified disease or abnormality, but only to exclude those in whom a definitely deviating growth pattern has been found, i.e. the boy with cranial synostosis and the two extremely obese children. Three girls who became pregnant between the age of fifteen and sixteen have been excluded from the latter age.

Measurement of children who later left the study have been included in the reference values with the exception of four children. In three of them subsequent somatic development is unknown (see case no. 1, 2 and 4 in Table 4), while the fourth child had only been examined three times during the first year of life.

Measurements on twins have also been retained in the analysis. There are three pairs of twins, one being of unlike sex and two of the male sex. One of the latter is probably a monozygotic pair, while the other is a dizygotic pair. The somatic growth of the monozygotic twins has been very near the average for all the various body measurements.

Missing examinations

Of the 179 children remaining in the study at the age of sixteen, 104 had been examined according to schedule at every age, while 16 of them had missed three or more examinations (Table 5). In comparison with the maximum number of examination (4.452), i.e. if the original 212 children had been examined at every age) there are 450 (10.1%) missing examinations, of which 278 (6.2%) are due to the fact that some children have left the study at various ages. In four fifths of the remaining 172 (3.9%) missing examinations measurements have been made both before and after the missing examination. In these cases we decided to interpolate the missing values. However, if it is the first or last examination of an individual that is missing, no extrapolation has been done. (As the children will be measured to as least 18 years, some values at 15 and 16 years can be interpolated later on, thus increasing the number of measurements at these ages).

TABLE 5
Number of missing examinations in children remaining in the study at the age of 16 years.

Number of missing examinations	Number of BOYS	GIRLS
Examined at all ages	61	43
1	28	17
2	5	9
3	3	4
4	7	2

There are two main reasons for the decisions to interpolate. In statistical analysis of longitudinal growth pattern it is necessary to have a value of measurement for each individual at each age included. One way of complying with this condition is to include only children who have been measured on every occasion. But the number of available children will then be rather low. Furthermore, such a group of children will probably not constitute a representative sample of children. In the present study only 58.1% of the children attended every examination (Table 5). The other reason for interpolating is that to exclude children with missing examinations would be to discard valid information. This applies to analyses of both longitudinal and cross-sectional character.

It should also be observed that in addition to missing values of all body measurements at a certain age (a missing examination), there may be missing values of single body measurements. For example, during infancy is has not always been possible to take all body measurements because of protests from some children. The excluded body measurements discussed above are also replaced by interpolated values. In all, about 4% of the values of measurements have been interpolated.

Interpolation of missing examination

If one single value of a body measurement was missing, interpolation was done by using a computer routine described below. If subsequent values were missing, interpolation was done by hand, using individually plotted growth curves of the various body measurements. Interpolation has been done exactly to the target ages, i.e. 5.0 years, 6.0 years etc. During puberty etc. only weight, standing and sitting heights have been interpolated in this way and then only if the missing values were confined by a measurement three months before and after. (From the age of ten years these three body measurements were [illegible] every third month).

Instead of using a straight line interpolation in the computer programme we have imitated the true growth by calculating a curved line in the following was (see also Fig. 3):

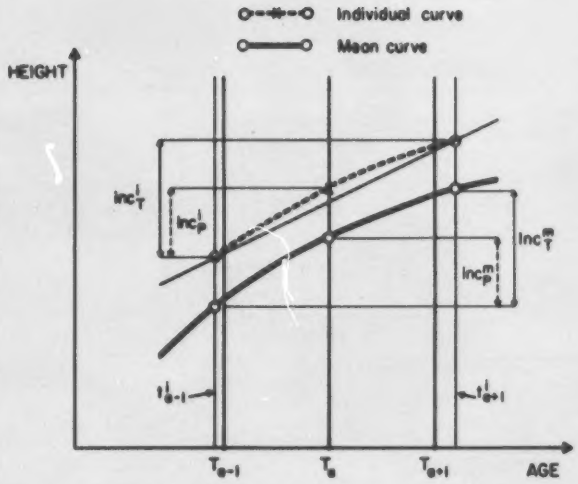

Fig. 3 Graphical representation of the method used for the interpolation of missing values.

1. Suppose, for example, that the standing height of an individual has not been measured at target age T_a, but at target ages T_{a-1} and T_{a+1}. In practice, the individual has not been measured exactly at these target ages but at t_{a-1} and t_{a+1} (Figure 3). The height of the individual at these ages is designed h^i_{a-1} and h^i_{a+1}.

2. A second-degree polynomial is then fitted to pass exactly through the mean values of standing height at the target ages T_{a-1}, T_a and T_{a+1}. Since the various children have not been measured exactly at the target ages, the ages of the mean values will differ somewhat from them. However, the differences are quite small, the maximum being 0.014 years, and are thus of no practical importance.

3. The values of the fitted mean curve at the age of t^i_{a-1}, T_a and t^i_{a+1} is designed h^m_{a-1}, H^m_a and h_{a+1}. The increment of the mean curve between the two ages at which the individual was measured, and the increment between the age at the first measurement and the age at the missing examination of the individual are then calculated. These increments can be expressed as:

$$Inc^m_T = h^m_{a+1} - h^m_{a-1} \text{ and } Inc^m_P = H^m_a - h^m_{a-1}$$

4. The increment of the individual between the two measurements performed is then calculated. This increment can be expressed as:

$$Inc^i_T = h^i_{a+1} - h^i_{a-1}$$

If the height at the missing examination is designated H^i_a, the increment of the individual from the first measurement to the missing examination can be expressed as:

$$Inc^i_P = H^i_a - h^i_{a-1}$$

5. By assuming that the ratio of the increment of the individual from the first measurement to the missing measurement, and the increment from the first to the second measurement of the individual will be the same as the ratio between corresponding increments of the fitted mean curve, the height of the individual at the missing examination (target age (T_a) can be calculated. The mathematical expression of the interpolated height of the individual at the missing examination will be

$$H^i_a = h^i_{a-1} + \frac{H^m_a - h^m_{a-1}}{h^m_{a+1} - h^m_{a-1}} \times (h^i_{a+1} - h^i_{a-1})$$

The procedure is illustrated in Fig. 3, in which a straight line has also been drawn between the two points of measurement of the individual in order to demonstrate the difference between our approach of interpolation and that made by drawing a straight line.

Adjustment to exact age

Three hundred and twenty-seven (8.2% of the examinations) have been performed outside the recommended intervals (see above), thus accentuating the problem of obtaining unbiased estimates of the mean and standard deviation. If there is a tendency, for example, to be late, the mean value will be too high and if the individual ages extend over a range the standard deviation will be too high (14). In longitudinal studies, where the aim is to examine the children at certain target ages, the difference between the non-corrected mean and the true mean of the sample will be relatively small for measurements analysed as distance values, e.g. height at a certain age. But when calculating growth rates (velocities) it is essential to have equal ages in all chil-dren. The tolerance limits set in the present study after the age of 2 years are from 2 weeks before to 4 weeks after target age. Accordingly: the longest interval between two successive examinations, both falling within the indicated limits, will be 58 weeks and the shortest interval 46 weeks. The difference between these extreme values is 12 weeks or about 25% of the intended interval.

Such wide variations cannot be tolerated. The actual examination ages have to be corrected to the exact target ages. Straight line interpolation was used for adjustment to the exact target age. If the example was made after the target age interpolation was done from the preceding examination and if the examination was made before the target age interpolation was done to the succeeding examination.

To summarize, the following editorial procedures have been undertaken: 1. Correction of administrative faults and exclusion of definitely aberrant values of measurement; 2. Exclusion of children with an aberrant growth pattern; 3. Interpolation of missing examinations; 4. Adjustment to the exact target age of each measurement.

RESULTS

Body measurements have been analysed for boys and girls separately. Mean values with standard deviation (SD) as well as centiles (10th, 50th and 90th) have been calculated both for distance values and for increments. The centiles have been calculated directly on the raw values. All increments are given as increase per year (= 12 months). Logarithmic transformations have also been made for weight (^{10}log (reading in 0.1 mm − 18)), the latter in accordance with Edwards et al. (7). The values of the various body measurements (distance values and increments) are given in Table 8 – 52, in which values of skewness and kurtosis have been included in order to indicate the distributions. With sample sizes like those in the present study the probability of finding a Gaussian distribution with values of the above statistical parameters outside the following intervals: ± *0.06 for skewness* and *2.2 – 4.4 for kurtosis* will be less than 1%.

Distance values

For linear measurements a relatively good fit to Gaussian distribution has been found with the exception of humerus bicondylar width and pelvic width during the first two years in both sexes, and femur bicondylar width from 6 – 12 years in boys. Especially in boys, circumference measurements have skewed distribution from 6 – 12 years. The distributions of weight and skinfolds are skewed if analysed with numerical values, but the use of the logarithmic transformations specified above gives better fit to Gaussian curves (Fig. 4). It should be observed, however, that the subscapular skinfold still has a skewed distribution from 7 – 16 years in boys and between 4 and 12 years in girls.

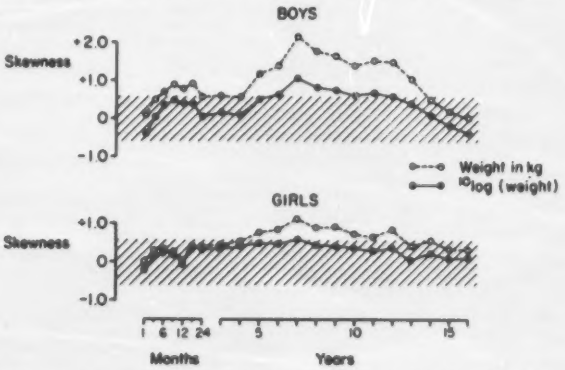

Fig. 4 Comparison of the skewness of the distribution of body weight using numerical values and a logarithmic transformation.

Increments

Skewed distributions of increment are more common than of distance values. However, for some linear measurements (supine length, crown-rump length, standing

height, sitting height and biacromial width), skewed distributions are found only at isolated ages.

During puberty the increments given in this paper are not representative of the individual variations with regard to the maximum pubertal growth of the various body measurements, as this will occur ad different ages in different children. Some data on the individual growth spurt in height are given in the paper on pubertal development in this publication (35).

Sex differences

The sex differences were of varying magnitude for the distance values of different body measurements (Table 6a – c). At most ages no statistically significant sex differences could be established for increments of various body measurements, the period of puberty being an exception (Table 7a – c).

Statistically significant sex differences were found for distance values of weight up to the age of two years and of height up to four years, with boys having the greater values (Table 6a). Girls weighed more than boys from 6 – 14 years, but the difference was only significant at twelve and thirteen years. The annual increment of weight was significantly greater in girls between ten and twelve years (Table 7a).

Mean values of height were greater in girls from eleven to thirteen years, but the sex differences were not statistically significant (Table 6a). However, the annual increment of height was significantly greater in girls between nine and twelve years (Table 7a). From thirteen years the increments of height and weight were greater in boys, but the attained values did not exceed those of girls until the age of fifteen (height) and sixteen years (weight).

Skeletal dimensions, estimated by femur and humerus bicondylar width and head circumference, were greater in boys at all ages (Table 6b).

Skinfold was consistently greater in girls, the sex difference being accentuated during puberty, when girls accumulate fat (Table 6c and Table 49 – 52). During the first few years the sex differences of limb circumference measurements were small, but from 8 – 13 years girls had a significantly greater upper arm circumference and from 5 – 15 years a greater calf circumference (Table 6c). At 16 years calf circumference was still larger in girls, but at this age boys had developed a greater mean upper arm circumference. As biceps and triceps skinfolds were decreasing in boys at this age period (Table 49 – 50), this pattern of growth may be taken as an indirect sign of an increasing muscular mass in boys.

TABLE 6a. Sex differences in the various body measurements as **distance values** *(t-test).*

Age in months	Weight[a]	Supine length	Crown-rump length	Standing height	Sitting height	Pelvic width	Biacromial width
1	+	+	(+)			+ +	+
3	+ +	+ + +	+ + +			(+)	+
6	+	+ + +	+ +			(+)	+
9	+	+ + +	+ + +			(+)	+
12	+	+ + +	+ +			(+)	(+)
18	+ +	+ +	+			+	(+)
Years							
2	+	+	+			+	(+)
3	(+)	+	+	+	+	(+)	(+)
4	(+)	+	+	(+)	+ +	(+)	(+)
5	(+)	(+)	(+)	(+)	+	(+)	(+)
6	(–)	(+)	(+)	(+)	(+)	(+)	(+)
7	(–)	(+)	(+)	(+)	(+)	(+)	(+)
8	(–)			(+)	(+)	(+)	(+)
9	(–)			(+)	(+)	(–)	(+)
10	(–)			(+)	(+)	(–)	(–)
11	(–)			(–)	(–)	– –	(–)
12	– –			(–)	–	– – –	(–)
13	– –			(–)	– –	– – –	(–)
14	(–)			(+)	(–)	– – –	(+)
15	(+)			+ + +	+	– –	+ + +
16	+ +			+ + +	+ + +	(–)	+ + +

+ + + $p < 0.001$; + + $p < 0.01$; + $p < 0.05$; (+) n.s.; boys > girls
– – – $p < 0.001$; – – $p < 0.01$; (–) n.s.; girls > boys
[a]t-test on logarithmic values.

TABLE 7a. Sex differences in the various body measurements analyzed as increments *(t-test)*.

Age in months	Weight	Supine length	Crown-rump length	Standing height	Sitting height	Pelvic width	Biacro-mial width
1 – 3	+	+ + +	+ +			(–)	(+)
3 – 6	(–)	(+)	(+)			(+)	(+)
6 – 9	(–)	(–)	(+)			(–)	(+)
9 – 12	(+)	(–)	– –			(+)	(–)
12 – 18	(+)	(–)	(+)			(+)	(+)
18 – 24	(–)	(–)	(+)			(+)	(–)
Years							
2 – 3	– –	(+)	(+)				
3 – 4	(–)	(–)	(–)	– –	(+)	(–)	(–)
4 – 5	(–)	(–)	(–)	(–)	(–)	(–)	(–)
5 – 6	(–)	(–)	(–)	(+)	(–)	(–)	(–)
6 – 7	(+)	(+)	(+)	(+)	(+)	(–)	+ +
7 – 8	(–)			(+)	(+)	(–)	(–)
8 – 9	(–)			(+)	– –	– –	(–)
9 – 10	(–)			– – –	(–)	(–)	(–)
10 – 11	– – –			– – –	– – –	– – –	–
11 – 12	– – –			– – –	– – –	– – –	(–)
12 – 13	(–)			(+)	– –	– – –	(+)
13 – 14	+ + +			+ + +	+ + +	+ +	+ + +
14 – 15	+ + +			+ + +	+ + +	+ + +	+ + +
15 – 16	+ + +			+ + +	+ + +	+ + +	+ + +

+ + + $p < 0.001$; + + $p < 0.01$; + $p < 0.05$; (+) n.s.; boys > girls
– – – $p < 0.001$; – – $p < 0.01$; – $p < 0.05$; (–) n.s.; girls > boys

DISCUSSION

Comparison with other Swedish studies

Secular trend

When the children of the present study are compared with those of two older Swedish studies, one from 1883 (19) and one from 1938-39 (3), a secular trend with respect to body size can be seen (Figure 5). The increase of height has been proportionally greater than that of weight.

In Fig. 5 only growth during school age is shown, but a comparison of height and weight during infancy between Nordic children born at the beginning of this century and in the fifties has shown a similar secular trend (34).

Many factors have been discussed as possible causes of the secular trend, e.g. breaking up of genetic isolates (heterosis) and improvement of socioeconomic conditions, giving improved health and nutrition. Conspicuous social differences in body size were present in the two older studies (Fig. 5). Children of the upper social class were not only taller and weighed more at a certain

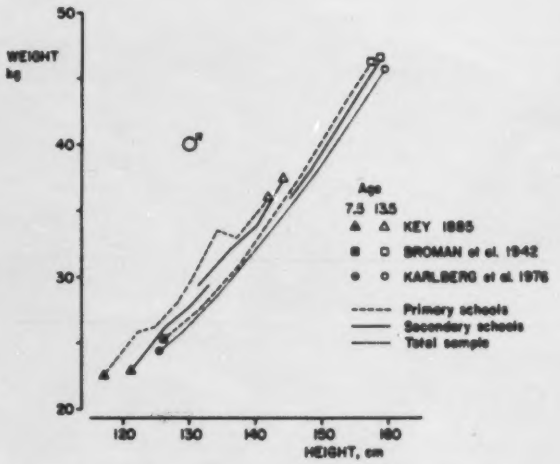

Fig. 5 Secular trend of height-weight-relationship in various Swedish investigations.

TABLE 6b. Sex differences in the various body measurements analized as distance values *(t-test)*.

Age in months	Anterior fontanel	Head circum-ference	Femur bicondy-width	Humerus bicondy-width	Thorax width	Thorax depth
1	(+)	+ + +	+	(+)		
3	(−)	+ + +	(+)	+		
6	(−)	+ + +	(+)	+ + +		
9	(−)	+ + +	+	+ + +		
12	(−)	+ + +	+	+ + +		
18	(−)	+ + +	+ +	+ + +		
Years						
2	(−)	+ + +	+ + +	+ + +		
3		+ + +	+ + +	+ + +		
4		+ + +	+ + +	+ + +		
5		+ + +	+ + +	+ + +		
6		+ + +	+ + +	+ + +		
7		+ + +	+ + +	+ + +		
8		+ + +	+ + +	+ + +		
9		+ + +	+ + +	+ + +		
10		+ + +	+ + +	+ + +	(+)	(+)
11		+ + +	+ +	+ + +	(−)	(−)
12		+ + +	+ + +	+ + +	(−)	(−)
13		+ + +	+ + +	+ + +	(−)	−
14		+ + +	+ + +	+ + +	(+)	(+)
15		+ + +	+ + +	+ + +	+	(+)
16		+ + +	+ + +	+ + +	+ + +	+ + +

+ + + $p < 0.001$; + + $p < 0.01$; < 0.05; (+) n.s.; boys > girls
− − − $p < 0.001$; − − $p < 0.01$; − $p < 0.05$; (−) n.s.; girls > boys

age but were also thinner, i.e. weighed less at a certain height. Differences in body size between social classes have been established by a number of studies (6, 12).

In view of the diminished social difference in body size during the last century (24) it is of interest that the secular trend of somatic growth seems to have ceased in social groups which during the last few decades have been living under what may be considered optimal conditions of life (5, 22).

For Swedish children there has not yet been any indication that the secular trend has ceased. The children of the present study seem to mature earlier and become taller than the children in the study of Broman et al. (3) made in 1938-39. The standing height of Swedish conscripts is also still increasing (personal communication, The Recruiting Administration of the Swedish Armed Forces, 1975).

The differences between the mean values of standing height in the present study and that of Broman et al. (3) are not consistent during the whole period of growth (Figures 6 and 7). During infancy the children of the older study were somewhat taller, but from the age of seven the children of the present study became increasingly taller until the age of 14-15 years. From these ages the numerical difference in height between the two studies began to diminish. The differences are statistically significant ($p < 0.05$ from 12-14 years in girls). In boys the difference became significant at thirteen years and was still so at the age of eighteen.

Broman et al. (3) recruited infants from nursery schools and at later ages children from primary schools (7-15 years) and secondary schools (10-20 years). At that time the upper social classes were over-represented not only in secondary schools but also in nursery schools (27). Accordingly, in comparison with a socioeconomically representative sample of children, greater mean values of body measurements were to be expected during childhood and after the age of fifteen in the study of Broman et al. (3). A confirmation of this statement can be found in the original paper of Broman et al. (3). In the standard tables the mean height of males at the age of 20 years is stated to be 178.4 cm, while in another table in the same publication the mean height of Swedish conscripts of the same age and born in the same year as the boys examined is only 174.6 cm. For comparison, it may be noted, that in the present study, consisting of a socioeconomically representative sample of children born in 1955-1958, the mean height of boys

TABLE 7b. Sex differences in the various body measurements analized as increments *(t-test)*.

Age in months	Anterior fontanel[a]	Head circum-ference	Femur bicondylar width	Humerus bicondylar width	Thorax width	Thorax depth
1 – 3	– –	+	(–)	(+)		
3 – 6	(–)	+ +	(+)	(+)		
6 – 9	(–)	(–)	(+)	(–)		
9 – 12	(+)	(+)	(+)	(+)		
12 – 18	(+)	(+)	(–)	(–)		
18 – 24		(–)	(+)	(+)		
Years						
2 – 3	(+)	(–)	(+)	(–)		
3 – 4		(–)	(+)	(+)		
4 – 5		–	+	(+)		
5 – 6		(–)	(–)	(–)		
6 – 7		(–)	(+)	(+)		
7 – 8		(–)	(+)	(+)		
8 – 9		(+)	(+)	+		
9 – 10		(+)	–	(–)		
10 – 11		(–)	(–)	(+)	(–)	–
11 – 12		– –	(+)	(+)	– –	–
12 – 13		– –	+ + +	+ + +	(+)	(–)
13 – 14		+ + +	+ + +	+ + +	+ + +	+ + +
14 – 15		+	+	+ + +	+ + +	+
15 – 16		+ +	(+)	+ + +	+ +	+ +

+ + + $p < 0.001$; + + $p < 0.01$; + $p < 0.05$; (+) n.s.; boys > girls
– – – $p < 0.001$; – – $p < 0.01$; – $p < 0.05$; (–) n.s.; girls > boys

[a]decrement instead of increment

who have so far reached the age of 18 years is about 179 cm, while the mean height of Swedish conscripts of the same age and born in 1955 was 178.6 cm (personal communication. The Recruiting Administration of the Swedish Armed Forces, 1975).

Thus, the inconsistency in difference of standing height between the present study and the investigation of Broman et al., (3) seems to be the effect of a non-representative sample in that study and not an indication that there has been no secular trend at some ages. It is essential to have comparable samples at all ages when drawing conclusions as to the existence of a secular trend or not.

Contemporary studies

In figures 6 and 7 two contemporary investigations of the growth of Swedish children are compared with the present study. Samuelsson (26) has published cross-sectional growth data on 1,400 children of three different ages (4, 8 and 13 years) living in a northern county of Sweden. Ljung et al. (21) have performed a mixed longitudinal study of height and weight from 10-17 years in 740 children living in 40 large cities and towns all over Sweden. The numerical differences between the mean values are small (less than 1 cm) except between girls in the present study and in that of Ljung et al. (21). The girls of the latter study are consistently 1-1 1/2 cm taller, but at no age is the difference statistically significant ($p < 0.05$, t-test). It should also be observed that the standard deviations of the girls in the study of Ljung et al. (1974) are consistently the smallest ones (Figure 7). However, the variance ratio (present study — study of Ljung et al. (21)) is statistically significant only at 16 years ($F = 1.66$; $p < 0.01$). This indicates that the girls in the study of Ljung et al. (21) may constitute a somewhat selected sample.

It is hardly probable that a difference in the timing of pubertal growth may have influenced the difference between the above studies as the age at menarche was quite similar, 12.94 years and 13.03 years in the study of Ljung et al. (21) and the present study respectively. In the study of Samuelsson (26) 64% of the girls had begun to menstruate at the age of 13.3 years.

TABLE 6c. Sex differences in the various body measurements analyzed as distance values *(t-test)*.

Age in months	Chest circumference	Upper arm circumference	Calf circumference	SKINFOLDS*		Subscapular	Suprailiac
				Biceps	Triceps		
1	(+)	(+)	(+)	–	–	– – –	– –
3	(+)	(+)	(+)	(–)	(–)	– – –	– –
6	(+)	(+)	(+)	(–)	–	– – –	–
9	(+)	(+)	(+)	–	(–)	– –	(–)
12	(+)	(+)	(+)	(–)	(–)	(–)	(–)
18	+ +	(2)	(+)	(–)	(–)	(–)	(–)
Years							
2	+	(+)	(–)	(–)	(–)	(–)	–
3	+	(–)	(–)	– –	–	– –	– – –
4	+	(–)	(–)	– – –	(–)	– – –	– – –
5	(+)	(–)	–	– – –	– – –	– – –	– – –
6	(+)	(–)	– –	– – –	– – –	– – –	– – –
7	(+)	(–)	–	– – –	– – –	– – –	– – –
8	(+)	–	–	– – –	– – –	– – –	– – –
9	(+)	–	–	– – –	– – –	– – –	– – –
10	(–)	–	–	– – –	– – –	– – –	– – –
11		–	–	– – –	– – –	– – –	– – –
12		–	–	– – –	– – –	– – –	– – –
13		–	–	– – –	– – –	– – –	– – –
14		(–)	(–)	– – –	– – –	– – –	– – –
15		(–)	–	– – –	– – –	– – –	– – –
16		(+)	(–)	– – –	– – –	– – –	– – –

+ + + $p < 0.001$; + + $p < 0.01$; + $p < 0.05$; (+) n.s.; boys > girls
– – – $p < 0.001$; – – $p < 0.01$; – $p < 0.05$; (–) n.s.; girls > boys

*t-test on logarithmic transformation

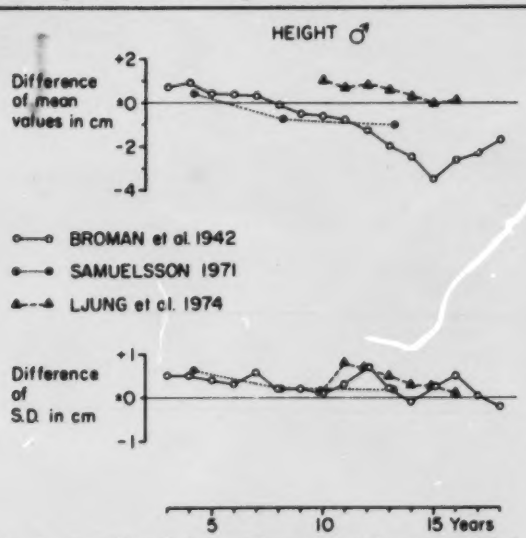

Fig. 6 Standing height of boys in various Swedish investigations. (The zeroline represents the values of the present study).

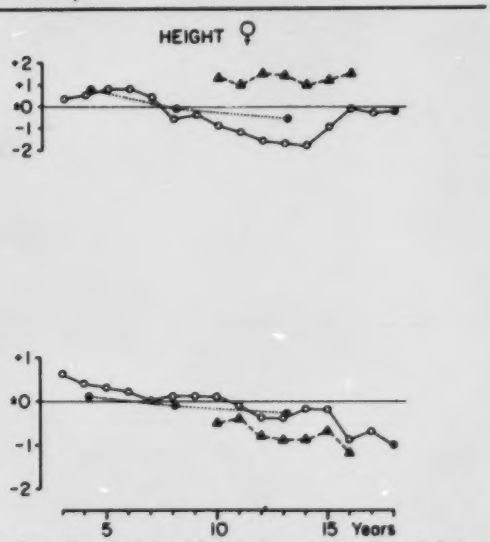

Fig. 7 Standing height of girls in various Swedish investigations. (The zeroline represents the values of the present study.)

TABLE 7c. Sex differences in the various body measurements analyzed as increments *(t-test)*.

Age in months	Chest circum-ference	Upper arm circum-ference	Calf circum ference	SKINFOLDS		Subsca-pular	Supra-iliac
				Biceps	Triceps		
1 – 3	(+)	(+)	(+)	(–)	(+)	+ +	(–)
3 – 6	(–)	(–)	(–)	(–)	(–)	(+)	(+)
6 – 9	(–)	(+)	(+)	(+)	(+)	(+)	(+)
9 – 12	(+)	(+)	(+)	(+)	(+)	+	(+)
12 – 18	+	(+)	(+)	(–)	(–)	(+)	(+)
18 – 24	(–)	(–)	–	(+)	(–)	(–)	(–)
Years							
2 – 3	(–)	–	(–)	– –	(–)	– –	(–)
3 – 4	(+)	(–)	(–)	(–)	(+)	(–)	(–)
4 – 5	(–)	–	–	(–)	– –	(–)	(–)
5 – 6	(–)	(–)	(–)	– – –	– –	(–)	–
6 – 7	(+)	(+)	(–)	–	–	–	– –
7 – 8	(–)	(–)	(+)	(–)	(+)	(–)	(–)
8 – 9	(–)	(–)	(2)	– –	(–)	– –	– –
9 – 10	–	(–)	(–)	(–)	(+)	(–)	– –
10 – 11		(–)	– –	(–)	(+)	(–)	(+)
11 – 12		(+)	(–)	(+)	(+)	(–)	(–)
12 – 13		(–)	(–)	–	(–)	—	
13 – 14		+	+ +	– – –	– – –	– – –	(–)
15 – 15		+ +	+	–	– – –	– –	–
15 – 16		+ + +	+	(+)	(–)	(+)	(–)

+ + + $p < 0.001$; + + $p < 0.01$; + $p < 0.05$; (+) n.s.; boys > girls
– – – $p < 0.001$; – – $p < 0.01$; – $p < 0.05$; (–) n.s.; girls > boys

Sitting height

Cross-sectional data on standing and sitting height from 11-16 years in 201 healthy Swedish girls have been published by Willner (37). The agreement between these values and those of the present study is good and there is no consistent trend in the numerical differences of the mean values between the studies.

Skinfolds

In the previously mentioned study by Samuelsson (26) subcutaneous skinfolds (triceps and subscapular) were also measured. The values reported are smaller than those of the present study for both boys and girls (Figure 8). As weight was somewhat greater at all three ages included in the former study, and height somewhat lower at two of them (8 and 13 years), this may indicate a different body composition of the children in the two samples. However, the differences are relatively small and not statistically significant.

Comparison with foreign studies

Standing height

Cross-sectional data of height and weight in contemporary school children in other Nordic countries have been published recently (1, 2, 4). In Fig. 9 these data have been plotted together with corresponding values from the present study and those for British children published by Tanner et al. (31, 32). The mean values of the Norwegian children (4) are consistently the greatest ones, but the differences compared to the Swedish children of the present study and the Danish children (1) are rather small; (the greater difference at 7 years is probably due to a sampling effect as the number of children examined at that age in the Norwegian study was only one-fourth of that at the other ages). The British children will have the shortest adult height, the difference in comparison with Scandinavian adults being 4-5 cm for males and 3-4 cm for females. At some ages the Finnish children (2) were shortest but from 16 years the lowest values are found amoung the British children.

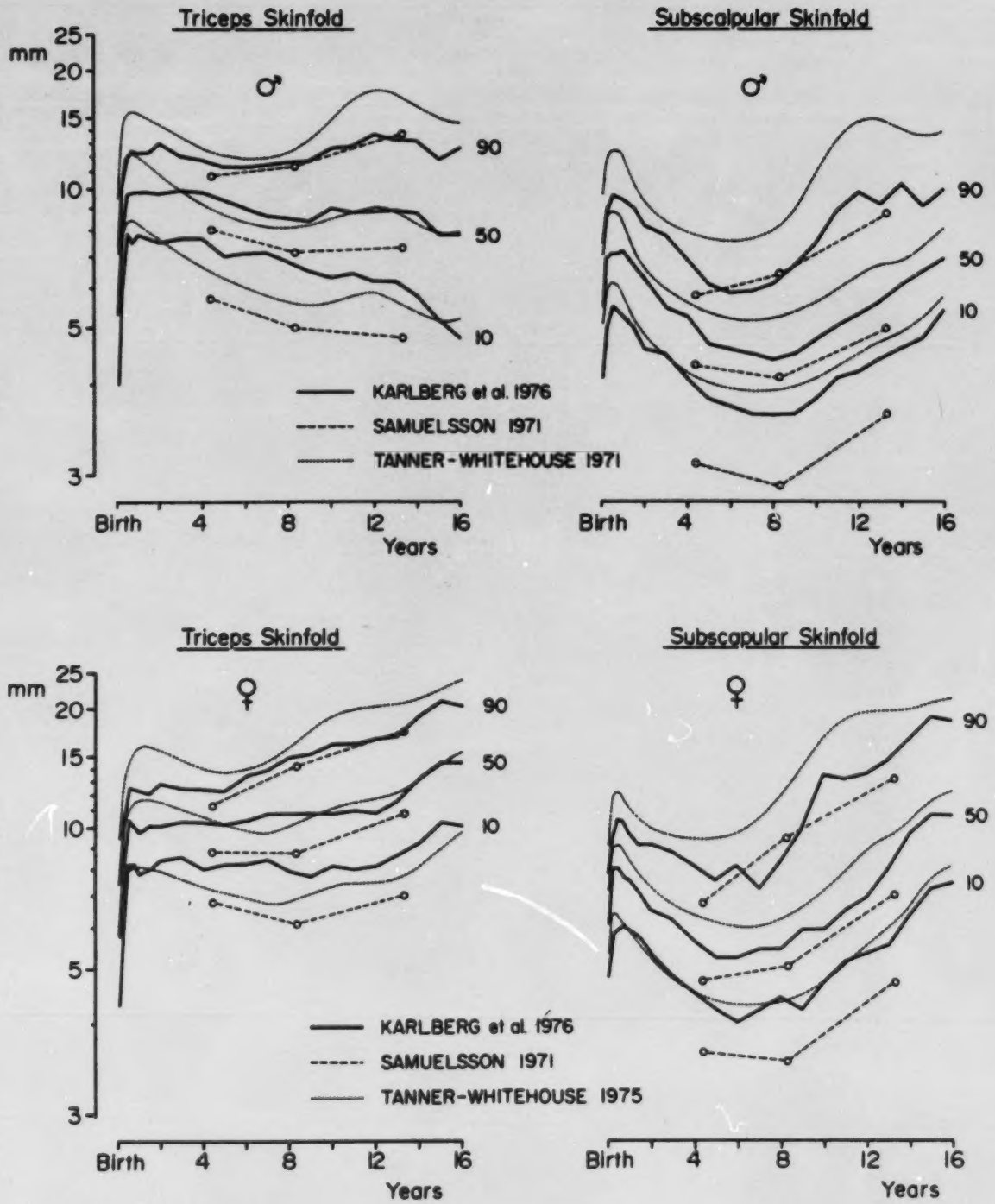

Fig. 8 Triceps and subscapular skinfolds in Swedish and British children (10th, 50th and 90th centile).

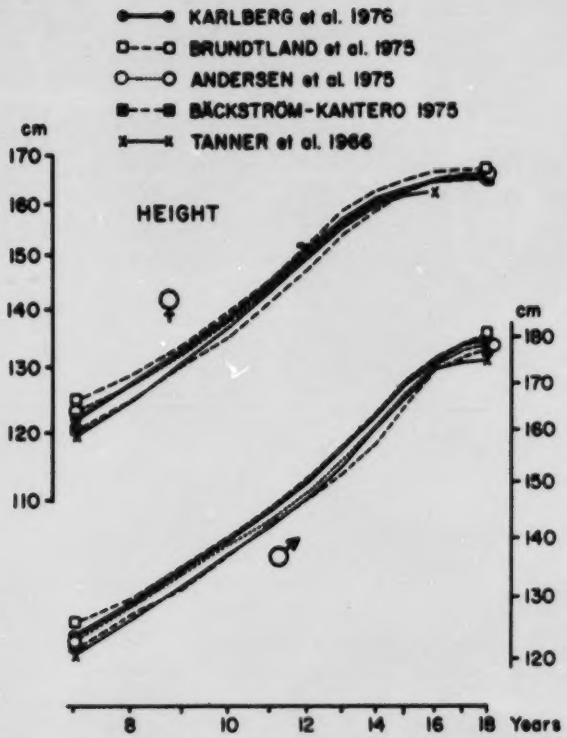

Fig. 9 Standing height from 7-18 years in Nordic and British children.

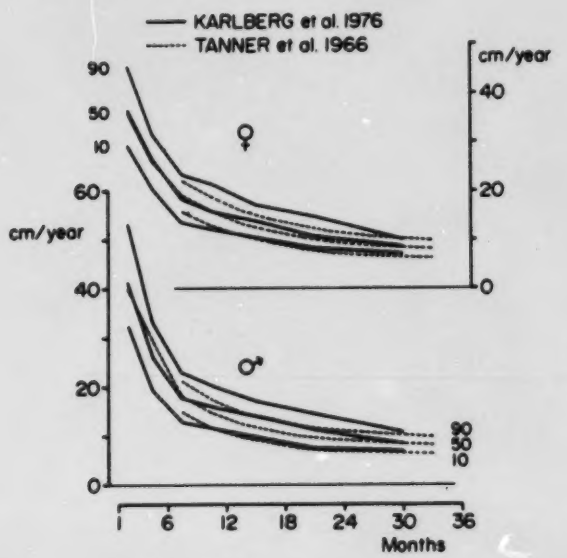

Fig. 10 Increments of linear body size from birth to 36 months of age of Swedish and British children (centiles).

Height velocity

In comparison with the velocity standards of height for British children published by Tanner et al. (31, 32)), the children of the present study had a greater growth in height from six months to two years (Fig. 10). During childhood the relative position of the centile curves of height (10th, 50th and 90th) of the two studies was not consistent but varied in both boys and girls (Fig. 11). The growth in height during puberty was greater in the boys of the present study. A similar tendency may have been present in girls, but the differences are less obvious.

The mean value of peak height velocity (PHV) in boys was 9.9 cm/year in the present study and 9.5 cm/year in the British study, while the corresponding values in girls were 8.6 and 8.4 cm/year, respectively. The mean age at PHV was quite similar in the two studies, 14.0 and 14.1 years in boys and 12.0 and 12.1 years in girls. In the present study PHV has been calculated by means of increments over twelve months based on height measurements taken every third month (for further details, see the paper on pubertal development in this publication (35). The values of the British study (31, 32) are the so-called whole-year centred PHV, which are the basis of the curve lines of the "repeated whole-year increments" in the British velocity diagrams.

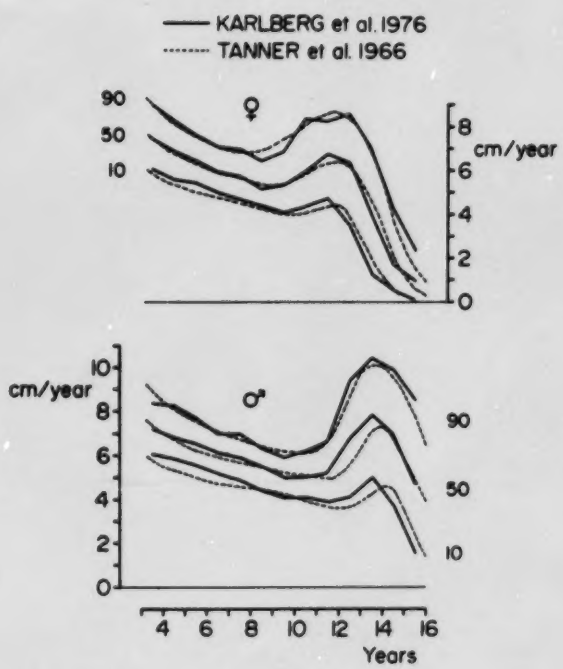

Fig. 11 Increments of standing height from 3-16 years in Swedish and British children (centiles).

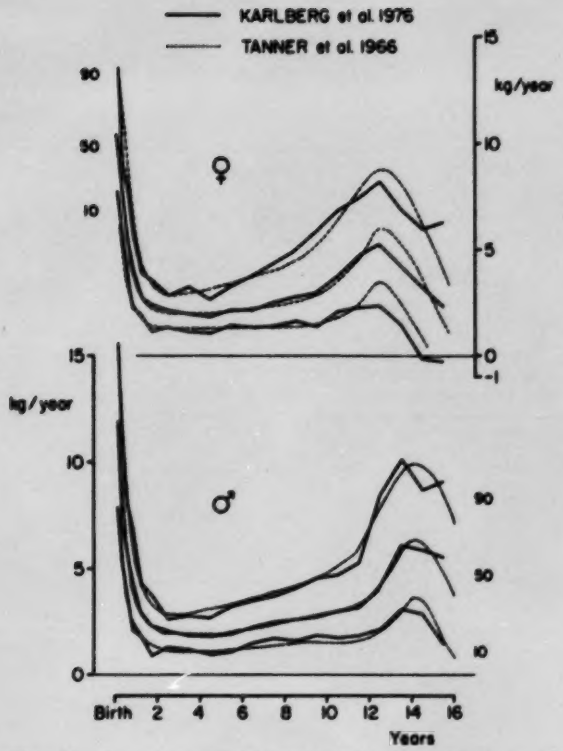

Fig. 12 Increments of body weight from birth to 16 years in Swedish and British children (centiles).

Weight velocity-skinfolds

When comparing weight velocity in the present study and that of Tanner et al. (31, 32) there is no definite difference for boys, while the pubertal weight gain seems to have been greater in the British girls (Fig. 12). Thus, there is a difference in the relationship between height and weight gain between the two studies, the British children tending to have a heavier body build. This is also evident from the distance values of height and weight at sixteen years, especially in girls. The girls of the present study were 2.1 cm taller but weighed 0.6 kg less (the latter difference is between median values), while the boys were 2.6 cm taller and weighed only 0.4 kg more. The skinfolds of British children also seem to be greater than those of Swedish children (Fig. 8).

Increments during infancy

Meredith & Meredith (24) published increment values of some body measurments during infancy in white, upper-middle-class North-american children. As they published only certain centile values (10th, 30th, 70th and 90th), and not median or mean values, only the curves for the 10th and 90th centile are represented in Figure 13. Their values were calculated as raw centiles on an equal number of children of each sex at the various ages. (No separate sex values are given, but this may be an acceptable procedure during this period of life, as no consistent significant sex difference of corresponding increment values has been found in the present study (Table 7). To derive comparable values from the present study the means of the relevant centile values for boys and girls have been plotted in Fig. 13). the growth curves of the increments of the various body measurements are quite similar and the difference between the centile lines strikingly small, although relatively low values of the 10th centile of some body measurements (upper arm circumference, biacromial width and pelvic width) have been found in the present study.

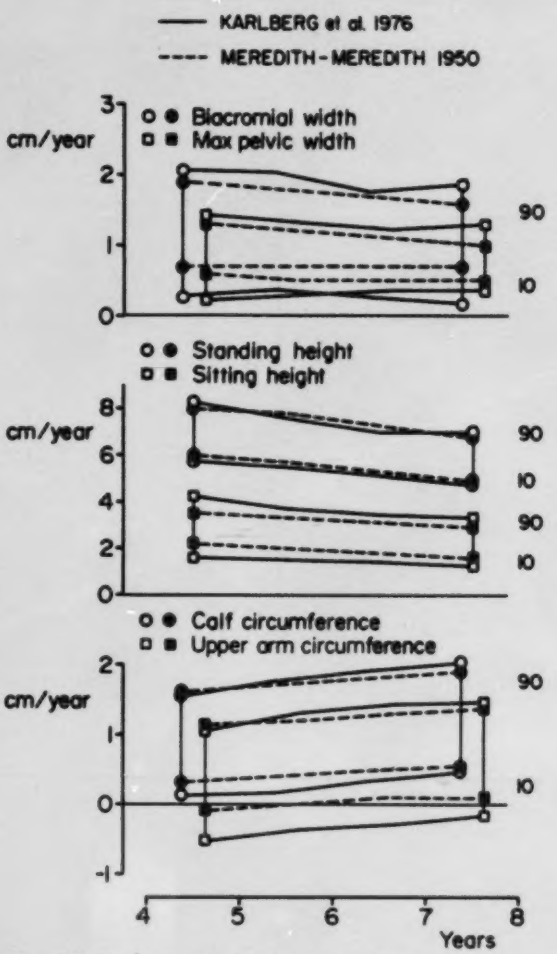

Fig. 13 Increments of various body measurements from 4-8 years in Swedish and North-American children.

Head Circumference

The importance of having not only a similar measurement technique but also comparable equipment is evident from a comparison of the method of measurement of head circumference used in the present study and the commonly used in Sweden at Infant Welfare Clinics. In the present study a narrow (0.6 cm) metal tape was used and the tape was firmly streched to minimize the influence of hair and subcutaneous tissue. (When measuring other circumferences (see Table 1) the tape was only loosely streched to bring it in contact with the skin.) At the Infant Welfare Clinics a wide (2 cm) plastic-linen tape is used and it is commonly rather loosely applied. A preliminary analysis of a compara-tive investigation (to be published) has shown a mean difference of somewhat more than half a centimeter between measurements made on children aged less than a year. The difference will be less is a similar amount of streching is applied, but the measurement taken with a narrow tape will definitely be less than that taken with a wider tape.

Such methodological distinctions may explain why, there may be small but consistent differences between the present and other studies (9, 17, 36) when analyzing the growth of the head circumferences by means of distance values, while there are no differences when comparing the velocity of the growth of the head circumference (Fig. 14). This indicates, that within each study the measurements have been done in a comparable way but that different techniques have been uses in the various studies.

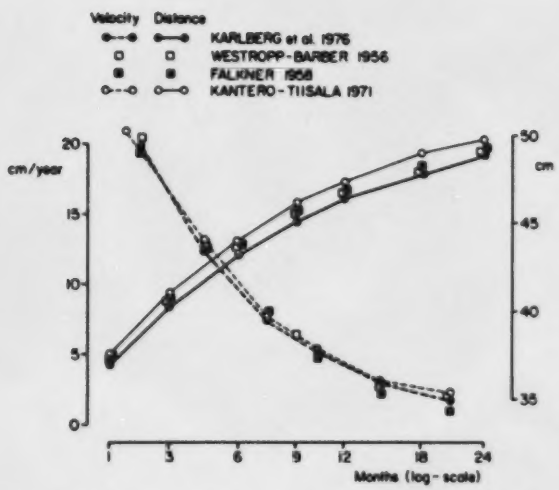

Fig. 14 Growth of the head circumference in various European investigations.

GROWTH DIAGRAMS

Standards deviations contra centiles

In the growth diagrams presented in this paper (Figures 15-18) the individual variation has been expressed in terms of the standard deviation. In principle, this requires a Gaussian distribution of the various body measurements. This is true for some of them, e.g. linear measurements, such as height and limb lengths, but not for others, e.g. weight and skinfold. However, it is possible to obtain Gaussian distributions of the latter measurements by suitable transformations (Figure 4). This is of importance as it has been shown that when there is a Gaussian distribution — or a distribution transformable thereto — there will be a substantial loss of information if individual variation is calculated by a non-parametric technique, e.g. centiles on the raw values (14). Tanner (28) has pointed out, that "it needs, in a Gaussian distribution, just four times as many (individuals) to estimate the 95th percentile with the same accuracy as the corresponding 1.65 SD level, and 14 times as many to estimate the 97.5 percentile with the same accuracy as its corresponding 2 SD level". Accordingly, the problem is to decide, where the smaller sampling error of the SD-method is outweighed by in increasing degree of skewness in the distribution, making the use of standard deviation less appropriate. So far no test has been elaborated that can be used for this decision. However, the difference between a fitted Gaussian distribution and the empirical distribution can be described, e.g. specifying the value of skewness and kurtosis, as has been done in this paper.

It is also essential to investigate, how existing differences will affect the evaluation of individual values of measurement, e.g. when using arbitrarily chosen limits to differentiate between healthy and unhealthy children in clinical work. Goldstein (13) analyzed the distribution of height in 655 girls aged 7.0-7.5 years by fitting a regression line of the mean value of the measurement to age and then calculating centiles by means of weighted resuduals. The estimate of centiles was aproximately the same as that based on standard deviation except at the ends of the distribution. At the upper end the estimated values began to deviate just above the level of + 2 SD and at the lower end somewhat above the level of − 2 SD. In comparison with the empirical distribution the Gaussian estimated values were too high at the lower end and too low at the upper end. In the example given by Goldstein (13) the difference in the estimate of the 3rd centile was 0.9 cm or about 0.14 SD-units.

Accordingly, if the SD-based estimate had been used, the proportion of children in the standardizing group below this limit would have increased by about one per cent. Since this bias is relatively small and is in a direction that makes the "normal" range more restricted, this cannot be regarded as a practical disadvantage from a clinical point of view, especially since the distributions of a certain measurement in healthy and unhealthy populations often overlap. Furthermore, it might be argued that the increasing deviation at the ends of the distribution indicates that some of the

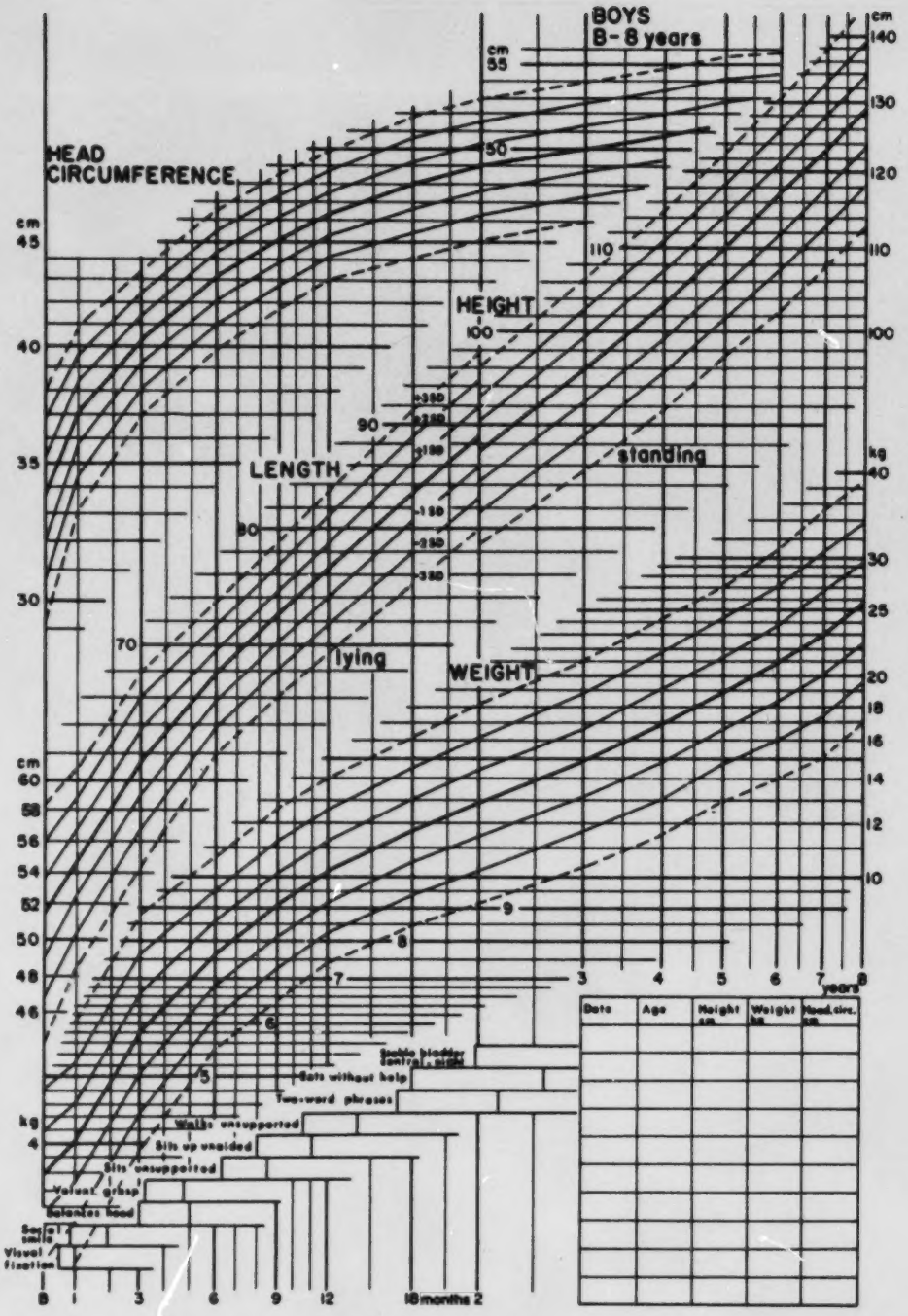

Fig. 15 Growth chart for supine length — standing height, weight and head circumference in boys from birth to 8 years including reference values of age at attainment of various skills during psychomotor development (± 1 SD (18).

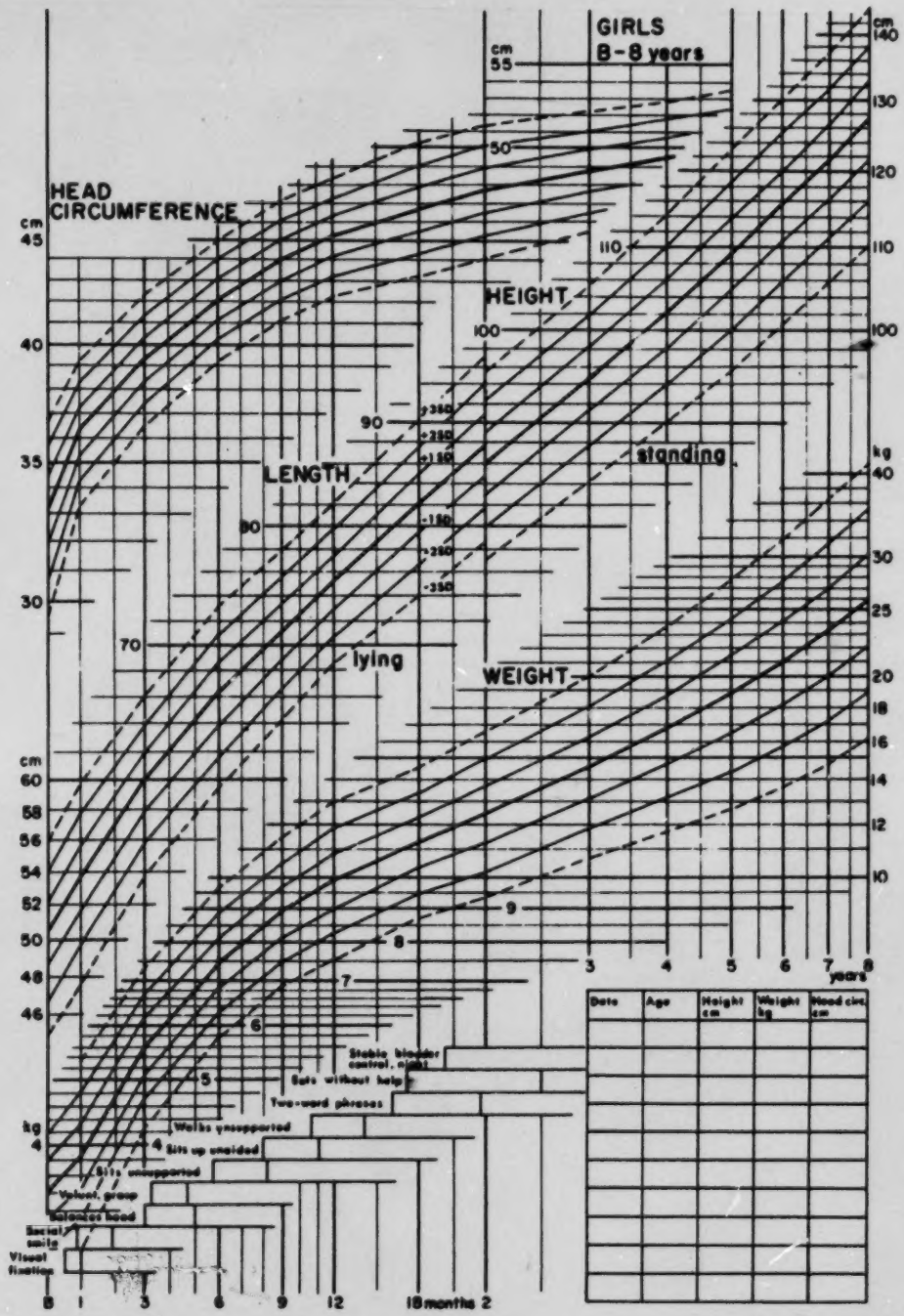

Fig. 16 Growth chart for supine length — standing height, weight and head circumference in girls from birth to 8 years including reference values of age at attainment of various skills during psychomotor development (± 1 SD (18).

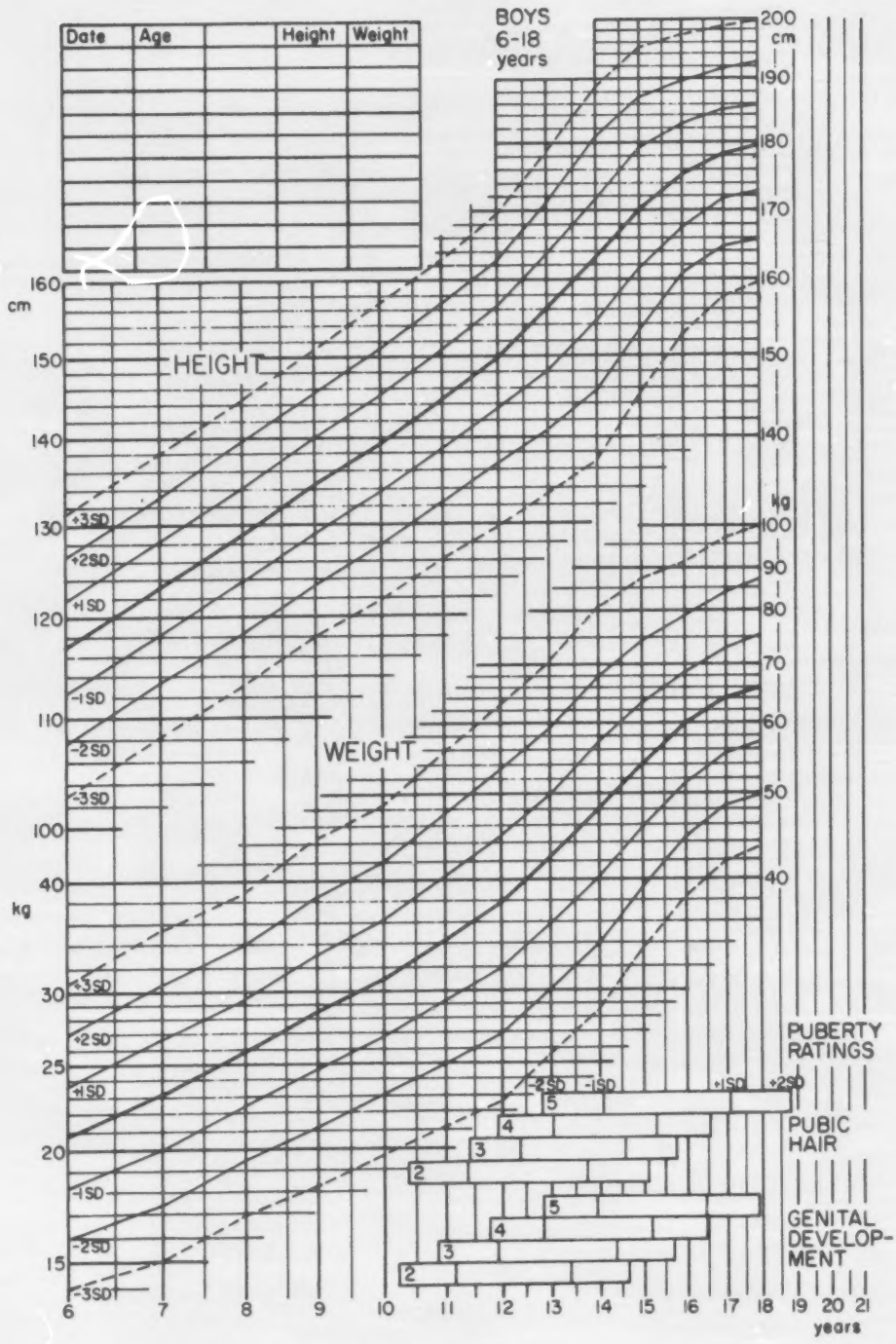

Fig. 17 Growth chart for standing height and weight in boys from 6-18 years including reference values of age at attainment of various physical signs of puberty (35).

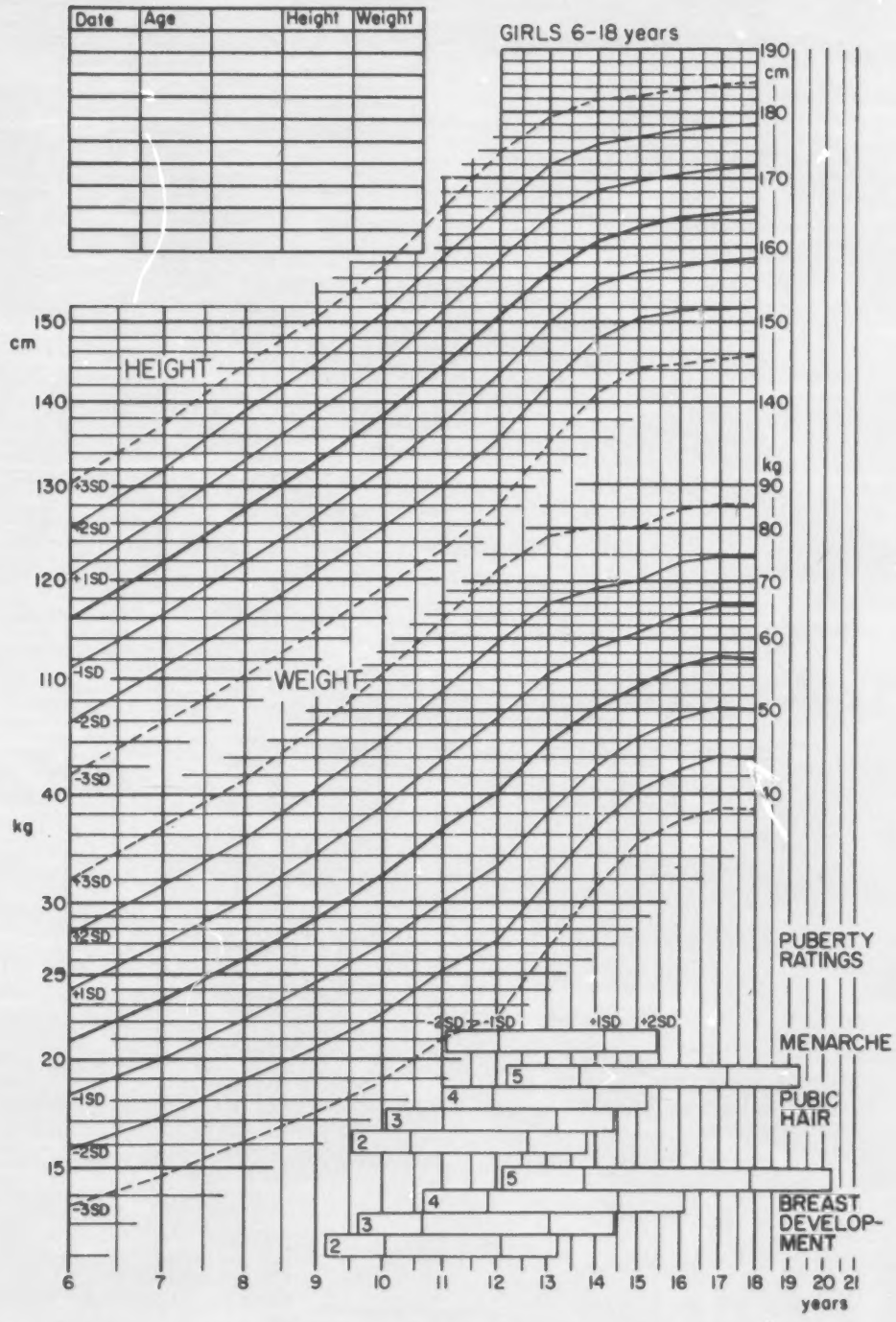

Fig. 18 Growth chart for standing height and weight in girls from 6-18 years including reference values of age at attainment of various physical signs of puberty (35).

children may belong to another (unhealthy?) population and thus should not be included in the calculation of normative reference values.

The size of the present sample (122 boys and 90 girls) is too small to allow any conclusions to be drawn from an analysis of the type suggested by Goldstein (13). But as long as the values of skewness and kurtosis are within certain limits (see p. 15), it may be assumed, at least for linear measurements, that the distribution of the various body measurements is similar to that found by Goldstein (13).

There is also an essential practical reason for the use of standard deviations instead of centiles. One of the main field for the application of growth diagrams is to evaluate measurements of children with grossly deviating growth, i.e. children with values of body measurement outside the range of ± 2 SD centile, corresponding to the 3rd-97th centile. Such values can always be measured in SD-scores but not in centiles. Furthermore, when examining a certain child on several occasions, the growth of the child can be more exactly described and evaluated by SD-scores than by centiles.

Logarithmic age scale

In the growth diagrams of the present study a logarithmic age scale has been used. Mathematically it is based on the conceptional age, which means that a full-term infant has an age of 38 weeks (0.73 years) at birth (B on the age scale of the diagrams). As the intensity of growth will decrease steadily from an early stage of the gestation, a logarithmic age concept will give biologically truer descriptions of growth. Furthermore, a logarithmic age scale is extended during the first few years of life, which will have practical advantages, as the evaluation of growth and development is usually at shorter intervals during this period of life than later. However, in order to facilitate the use of the diagrams age has been expressed in the diagram in units of usual postnatal age (birth age).

Logarithmic scale of the measurements

Logarithmic scales have also been used for the various body measurements, which means that the scales will be extended in the ranges of measurement during the first few years of life. This will also have practical advantages, as growth during this period of life is often evaluated at short intervals. Accordingly, the numerical change of the various body measurements will be relatively small. The variance of the different body measurements will increase with age. The increase is approximately proportional to the increase of the mean values. This means that on a logarithmic scale the distance between the mean value and a certain standard deviation will be about the same during the whole of the period of growth. Consequently, the deviation of individual measurements can be estimated in terms of SD-scores with the same precision irrespective of age, which is not possible with a numerical scale.

SUMMARY

Physical growth of 212 randomly selected Swedish urban children has been investigated from birth to sixteen years as part of a prospective longitudinal study of growth and development. Twenty body measurements have been taken at specified ages. In all, about 66,000 values of measurement have been recorded.

At sixteen years 179 (84.4%) of the original children were still regularly being followed. Thirty-three (15.6%) of the 212 children left the study at various ages. A comparison between the children who left the study and those remaining did not show any significant differences in physical growth.

All recorded data have been scrutinized in order to detect errors of measurements or administrative errors. Such values have been corrected or excluded. The editorial procedures also included the adjustment of each measurement to exact target age, interpolation of missing examinations and exclusion of children with an aberrant growth pattern.

When comparing the present study with older Swedish investigations a secular trend was established, while there was good agreement with other contemporary Swedish investigations.

Growth charts of distance values of various body measurements are presented. In the charts standards deviation lines (± 1, 2, 3 SD) and mean values are plotted. A logarithmic time scale (logarithmic conceptional age) has been used for both practical and theoretical reasons.

When evaluating individual values in comparison with reference values standard deviations should be used rather than centiles. With this approach even grossly deviating values can be evaluated. Longitudinal follow-up of individual children and comparison of children of different ages will also be facilitated by this approach.

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Longitudinal Study of Bowel and Bladder Control by Day and at Night in the First Six Years of Life. I:

Epidemiology and Interrelations between Bowel and Bladder Control*

Remo H. Largo, Werner Stutzle

INTRODUCTION

Knowledge about the development of bladder control and of bowel control determines the attitude towards toilet-training, and plays a part in aetiological and pathogenetic concepts about enuresis and encopresis. According to Mac Keith *et al.* (1973) and other authors, the development of nocturnal dryness is a process of maturation, complete by age five, which cannot be accelerated by training, but the behavior of dryness at night—wich depends on the maturation having taken place—can be delayed by various factors, such as stress between the ages of two and three years (Douglas 1973). The development of day-time dryness is probably also a process of maturation and may be positively influenced by toilet-training. The development of bowel control has been less thoroughly studied. At present the roles of maturation and toilet-training have been poorly defined (Bellman 1966, Silber 1969, Levine 1975).

Most of the literature describes only the development of bladder control, often only at night, or the development of bowel control. However, a more comprehensive approach seems to be desirable for the following reasons. First, in toilet-training the developmental processes of bowel control and of bladder control by day and at night should not be dealt with separately. Second, it might be of interest to know how these processes are related to each other.

The purpose of this study is to describe in detail the development of bowel control and of bladder control during the day and at night, and to report what interrelations exist between these three processes. Further, the relevance of this data for toilet-training and for the management of enuretic and encopretic children will be discussed.

SUBJECTS AND METHODS

From 1955 to 1976 a longitudinal study in growth and development of 413 healthy Swiss children was conducted at the Kinderspital Zurich, in co-operation with the Centre International de l'Enfance in Paris (Falkner 1960). These children form a representative selection of a Swiss urban population, according to the occupational status of the parents.

Before six months of age, data only on potty-training were obtained. After that age, data on the different stages of the development of bowel control and of bladder control are available for 72 children at nine months, for 96 children at 12 months, for 163 children at 18 months, and for 320 children at two years and thereafter (see Table 2 for the exact number of children examined).

The children were seen at the ages of one, three, six, nine, 12, 18 and 24 months, and thereafter at yearly intervals. The mothers reported the stage of bowel and bladder control by day and at night reached during the month before each examination. The following scoring system was used: 0 per cent = no control; 1 to 30 per cent = partial control during approximately one-third of the time; 30 to 70 per cent = control during one-third to two-thirds of the time; 70 to 95 per cent = total control except for a few relapses; and 100 per cent = total control. (For more detailed information see Falkner (1960) in which the complete questionnaires have been published.)

RESULTS

Incidence of potty-training, bowel and bladder control by day and at night.

Potty-training

At three months 13 per cent and at six months 32 per cent of the children were held on the pot by their mothers, a few being held over the lavatory. The majority were put on the pot at between six and 12 months, that is when they had learned to sit alone. At 12 months 96 per cent were being placed on the pot (Table 1).

TABLE 1

Potty training

Age (mths)	*Percentage of children put on pot*
1	3
3	13
6	32
9	80
12	99
24	100

* We acknowledge the authorization given by Spastics International Medical Publications to reproduce this paper appeared in Developmental Medicine and Child Neurology, 1977, 19, 598-606.

TABLE 2

Incidence of bowel control, bladder control by day and at night (%)*

Stage of control	*Age (yrs)* 9/12		1		1½		2		3		4		5		6	
	m	*f*	*m*	*f*	*m*	*f*	*m*	*f*	*m*	*f*	*m*	*f*	*m*	*f*	*m*	*f*
Bowel control																
0%	32	26	8	13	3	0	1	1	2	1	0	0	0	0	0	0
1 – 30%	18	16	14	11	5	5	7	1	0	0	0	0	0	0	0	0
30 – 70%	18	21	14	15	6	5	3	3	0	0	0	0	0	0	0	0
70 – 95%	24	24	32	22	29	25	16	12	2	1	2	3	2	1	1	1
100%	8	13	32	39	57	65	73	83	96	98	98	97	98	99	99	99
Bladder control, day																
0%	97	92	90	78	56	43	26	14	2	0	1	1	2	2	1	1
1 – 30%	3	4	8	11	15	29	10	10	1	1	1	0	0	1	2	0
30 – 70%	0	2	2	2	7	5	11	15	2	3	0	1	1	1	3	1
70 – 95%	0	0	0	9	12	7	36	39	78	78	9	9	5	4	3	1
100%	0	0	0	0	10	16	17	22	18	18	89	89	92	92	97	97
Bladder control, night																
0%	100	99	99	98	82	80	58	47	7	6	2	1	4	2	1	3
1 – 30%	0	1	1	2	10	6	13	11	11	6	4	2	1	2	3	0
30 – 70%	0	0	0	0	2	2	10	15	10	10	2	3	3	1	3	1
70 – 95%	0	0	0	0	4	6	12	18	56	56	15	8	6	6	3	2
100%	0	0	0	0	2	6	7	9	16	22	77	86	86	89	90	94
n	34	38	46	50	85	79	152	150	162	161	163	161	143	146	152	156

*Actual numbers of children are shown in bottom line of Table.

Bowel Control

By the end of the first year about 60 per cent of the children showed partial and about 35 per cent complete bowel control (Table 2). At two years about 75 per cent and at three years practically all the children were completely bowel-trained.

Bladder Control by Day

At age one 10 per cent of the boys and 20 per cent of the girls were partially dry by day, but none was completely dry (Table 2). At two years most of the children had at least partial baldder control, and about 20 per cent had complete bladder control. The third year shows no increase in completely dry children, but 78 per cent of them had a score of 70 to 95 per cent (dry except for a few relapses). At four years 89 per cent and at six years 97 per cent of the children were completely dry.

Bladder Control at Night

At the end of the first year very few children were partially, and none completely, dry at night (Table 2). At two years of age about 50 per cent of the children still had no bladder control, and only 8 per cent were completely dry. By three years most of the children were partially dry; about 20 per cent were completely dry, which was about the same percentage as those who have complete diurnal bladder control. During the fourth year the majority of the children became completely dry a night, and by six years more than 90 per cent had complete bladder control.

Complete Bowel and Bladder Control

Most children gained first bowel control, then bladder control by day and finally at night. So by the end of the third year about 75 per cent of the children had complete bowel control, but not complete bladder control by day and at night (Table 3). In addition to complete bowel control, diurnal bladder control (but not nocturnal) is reported in 5 to 14 per cent of the children. The majority gained complete bladder control by day, and subsquently also at night, during the fourth year of life. Therefore the proportion with complete bowel and bladder control during the day and at night was only 5 per cent at age two and 11 per cent at age three, but more than 75 per cent of the children at age four and

more than 90 per cent at age six were completely clean and dry by day and at night.

About 8 per cent of the children had a different pattern in their development of bowel control and bladder control. Between two and five years of age, 3 to 6 per cent achieved bowel control and bladder control at night, but not by day, and about 1 per cent were not clean and dry at night, but dry by day. Complete bladder control by day and at night without bowel control was seen only in exceptional cases.

Sex

Development of bowel control and of bladder control by day and at night commences and is completed earlier in girls than in boys (Table 2). For the following results, data of boys and girls are not separated, because there is no significant sex difference.

Interrelations between Bowel Control, Bladder Control by day and Bladder Control at Night

Bowel Control and Bladder Control by Day and at Night

χ^2 tests calculated from cross-tabulations of the intermediate stages of bowel and bladder control by day and at night show highly significant relationships (Table 4). The relevance of these data is shown in Table 5. Between 1½ and three years, only 2 to 6 per cent of the children with incomplete bowel control were dry by day and none was dry at night. However, 18 to 25 per cent of the children with complete bowel control were completely dry during the day and 5 to 19 per cent were dry at night. Therefore if bowel control was not complete, bladder control usually was missing or only partial, especially at night. If bowel control was complete, bladder control still could be missing or partial, but children with complete bowel control had a good chance of being dry by day, and also maybe at night.

Bladder Control by Day and at Night

The development of bladder control by day and of bladder control at night are closely related to each other (Table 6). Table 7 shows that between 1½ and three years only a few children were completely dry at night if they lacked day-time bladder control. If day-time bladder control was complete, however, about 25 per cent of the children at ages 1½ and two years were dry at night, and 65 per cent of those aged three and 86 per cent of those aged four were dry at night. Therefore children who are not dry by day usually are not dry at night. With complete diurnal bladder control there is a good chance of also being dry at night.

TABLE 3

Complete bowel control and/or bladder control by day and-or at night (%)

Bowel control	—	+	+	+	—	+	—	—
Bladder control by day	—	—	+	+	+	—	+	—
Bladder control at night	—	—	—	+	+	+	—	+
Age (yrs)								
9/12	89.5	10.5	0	0	0	0	0	0
1	64.5	35.5	0	0	0	0	0	0
1½	36.8	49.7	8.8	2.8	0.9	0	1.0	1.0
2	21.7	54.8	13.8	5.4	1.0	2.6	0.7	0.7
3	2.8	73.7	5.4	10.9	0.3	5.9	1.0	1.0
4	2.0	6.0	11.3	76.6	0.3	3.5	0.3	0.3
5	0.3	3.1	7.2	85.5	0.3	0.3	0.6	0.6
6	0.6	1.2	5.1	91.3	0.6	0.9	0.3	0.3

Discussion

In 1955, most of the Swiss children in this study were put on the pot when they were able to sit alone, and in 96 per cent toilet-training was started by the end of the first year*. Similar data in other European countries at the same period are reported by Douglas (1958) and Hindley (1968). With this early onset of toilet-training, bowel control and bladder control developed very differently. Whereas 30 per cent of the children were completely bowel-trained at age one, and 97 per cent at age three, none of them was dry by day or at night at age one, and only 20 per cent at age three. About 80 per cent of the children had been sitting on the pot for more than two years before they accomplished bladder control by day and at night during the fourth year of life. In agreement with Klackenberg (1971) and Lovibond (1964), and in contrast to Young (1964), this leads us to suppose that at least the development of bladder control can hardly be accelerated by training. Further evidence

* Preliminary data of the second Zurich longitudinal study shows that in 1974 less than 5 per cent of the Swiss children were put on the pot during the first year of life.

TABLE 4

Relationships* between bowel control and bladder control by day and at night, 1 to 3 years of age

Age (yrs)	*Correlations between bowel control and*	
	Bladder control by day	*Bladder control at night*
1	$p < 0.05, \chi^2 = 30.8$	$p < 0.05, \chi^2 = 26.4$
1½	$p < 0.001, \chi^2 = 91.5$	$p < 0.001, \chi^2 = 76.4$
2	$p < 0.001, \chi^2 = 107.9$	$p < 0.001, \chi^2 = 53.6$
3	$p < 0.001, \chi^2 = 101.5$	$p < 0.001, \chi^2 = 86.2$

*χ^2 and p-values of cross-tabulations of the intermediate stages of bowel and bladder control (df = 16.)

TABLE 5

Incidence of complete bladder control by day and a night at a given stage of bowel control, 1½ to 4 years of age

Stage of bowel control	*Percentage with complete bladder control at age of*			
	1½ *yrs*	2 *yrs*	3 *yrs*	4 *yrs*
0 – 70%	5/0*	4/0	0/0	0/0
70 – 95%	6/2	2/0	(2/6)/(1/6)†	(1/3)/(2/3)†
100%	18/5	25/11	17/19	90/84

*Percentages by day/at night.
†These numbers were too small to give percentages, so proportions of children are shown, *e.g.* 2 out of 6, 1 out of 6.

TABLE 6

Relationship* between bladder control by day and bladder control at night, 1 to 5 years of age

Age (yrs)	
1	$< 0.01, \chi^2 = 33.2$
1½	$< 0.001, \chi^2 = 111.2$
2	$< 0.001, \chi^2 = 132.6$
3	$< 0.001, \chi^2 = 126.4$
4	$< 0.001, \chi^2 = 143.5$
5	$< 0.001, \chi^2 = 123.4$

* χ^2 and p-values of cross-tabulations at intermediate stage of bladder control by day and at night. (df = 16.)

for this assumption is given elsewhere (Largo and Stutzle 1977).

Our data on bladder control between one and three years of age are not consistent with those of other authors who report a higher percentage of dry children by day and at night in this age group (see review by de Jonge 1973). The reason for this difference is, we assume, that in our study mothers were asked not only whether the child was dry or not, but also at what intermediate stage he was. So at age three, 20 per cent of the children were completely dry by day and at night, but 75 per cent had a score of 70 to 95 per cent for bladder control by day and at night; that is, they were dry except for a few relapses during a one-month period. We believe that in most studies these children with nearly complete bladder control have been classified as completely dry. At ages four and five, in agreement with most authors (de Jonge 1973), 80 per cent and 90 per cent respectively are dry by day and at night. Consistently, the development of bowel and bladder control was found to be slightly more advanced in girls than in boys.

Our data tend to show that a similar developmental process is responsible for diurnal and nocturnal bladder control, and also for bowel control. In more than 90 per cent of our children there was a high correlation between, first, the development of bowel control, then diurnal bladder control. These findings give further evidence that it is mainly the process of maturation which determines the development of bowel and bladder control. The practical relevance of these interrelations can be summarized as follows: (1) Without complete bowel control it is unlikely that a child is dry during the day and it is very unlikely that he is dry at night. With complete bowel control, bladder control can still be missing or partial: however, children with complelte bowel control have a good chance of being dry by day and may be also at night. (2) Children with incomplete bladder control by day are usually not dry at night. Not all children with complete diurnal bladder control are dry at night, but there is a good chance that they will be.

In some children the development of bowel and bladder control may be different. 3 to 6 per cent of our children between two and five years of age were clean and dry at night, but not dry by day. An even higher incidence of children dry at night but not by day at age 2½ years is reported by Roberts and Schoellkopf (1951). About 1 per cent of our children were dry by day, without being clean and dry at night.

The development of bowel control essentially is completed by the end of the third year and that of bladder control by the fifth to sixth year. The latter finding is in agreement with Mac Keith (1973), who states that maturation in nocturnal bladder control is complete in 98.5 per cent of the population by age five. Based on our results, what conclusions can be made about disorders in bowel and bladder control after the third of fifth year respectively? Concerning encopresis, bowel control is completed in practically all children before bladder control is complete. Therefore, if children with complete bladder control lack bowel control, this cannot

TABLE 7

Incidence of complete bladder control at night at given stage of bladder control by day, 1½ to 5 years of age

Stage of bladder control by day	*Complete bladder control at night at age of* 1½ *yrs*	2 *yrs*	3 *yrs*	4 *yrs*	5 *yrs*
	%	%	%	%	%
0 – 70%	—	0.5	7	—	—
70 – 95%	—	7	8	48	65
100%	28	25	65	86	93

be attributed to a maturational delay. Concerning enuresis diurna, daytime dryness is usually achieved prior to or concurrent with nocturnal dryness. Thus enuresis diurna in a child completely dry a night is scarcely ever due to a delay in maturation. However, if a child has primary enuresis nocturna (in the sense that he is wet every night) and had developed bladder control by day and bowel control unusually late, a delay in maturation may be a sensible explanation. With the understanding that becoming clean and becoming dry by day and at night may be one unique maturation process, a detailed history of the development of bowel and bladder control in enuretic children should be obtained. It might help to clarify further the presence or absence of delayed maturation in such cases.

Acknowledgements: We thank Prof. A Prader, Kinderspital Zurich, for his helpful criticism in the preparation of this paper, and Miss M. Meyer for her secretarial work.

AUTHORS' APPOINTMENTS

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SUMMARY

The development of bowel and bladder control by day and at night during the first six years of life in 320 Swiss children in the Zurich longitudinal study (1955-1976) is described in detail. A scoring system was used which included intermediate stages of control. With toilet-training started in 96 per cent of the children during the first year of life, bowel control was completed in 32 per cent at age one, in 75 per cent at age two in 97 per cent at age three. Complete bladder control by day and at night were established in none of the children at age one, in 20 per cent at ages two and three and in 90 per cent at age four. Complete bowel control and complete bladder control by day and a night were found in 5 per cent at age two, in 11 per cent at age three, in 77 per cent at age four and in 91 per cent at age six.

The significant relationships between bowel control, bladder control during the day and bladder control at night ($p < 0.001$) demonstrate that the same developmental process acts in bowel and bladder control. Highly correlated to each other, first bowel control develops, then bladder control by day and finally bladder control at night. The relevance of these interrelations for toilet-training and for the management of enuretic and encopretic children is discussed.

RÉSUMÉ

Le développement du contrôle rectal et vésical de jour et de nuit au cours des six premières années de la vie chez 320 jeunes enfants est décrit en détail, à partir d'un système de notation qui comprend les stades intermédiaires du contrôle. L'apprentissage de la propreté a débuté chez 96 pour cent des enfants dans la première année de la vie, le contrôle rectal est acquis chez 32 pour cent à l'âge de un an, 75 pour cent à l'âge de deux ans et 97 pour cent à l'âge de trois ans. Le contrôle vésical complet de jour et de nuit n'est jamais observé avant l'âge d'un an, dans 20 pour cent des cas aux âges de deux et trois ans et 90 pour cent à l'âge de quatre ans. Le contrôle rectal complet et le contrôle vésical complet de jour et de nuit ont été notés chez cinq pour cent des enfants à l'âge de deux ans, 11 pour cent à l'âge de trois ans, 77 pour cent à l'âge de quatre ans et 91 pour cent à l'âge de six ans.

Il a été trouvé une relation significative ($p < 0,001$) entre le contrôle rectal, le contrôle vésical de jour et le contrôle vésical de nuit, ce qui suggère qu'un même processus de développement agit à la fois sur le contrôle rectal et le contrôle vésical. Le contrôle rectal se développe en premier, puis le contrôle vésical de jour et enfin le contrôle vésical de nuit. Les conséquences de ces relations pour l'éducation de la propreté et le traitement des enfants enurétiques et encoprétiques sont discutées.

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Longitudinal Study of Bowel and Bladder Control by Day and at Night in the First Six Years of Life. II:

The Rôle of Potty Training and the Child's Initiative*

Remo H. Largo, Werner Stutzle

INTRODUCTION

Can the development of bowel control and of bladder control by day and night be accelerated by training? Controversial opinions on this subject have been expressed by various authors (Klackenberg 1955, Lovibond 1964, Hundziak *et al.* 1965, Pumroy and Pumroy 1965). Assuming that the development of bowel and bladder control is mainly a process of maturation (Barbour *et al.* 1963, Illingsworth 1968, Bakwin and Bakwin 1972, Largo *et al.* 1977), it would be logical to deny a positive effect of training. At best, training might shorten the period between completion of the maturation process and emergence of the corresponding behaviour, *e.g.* to pass stool or to void urine into the pot. A negative effect of training is far more easily conceivable, in that forceful educational methods may hamper the emergence of the long-desired behaviour, although the maturation process has been completed.

The object of this study is to investigate that aspect of toilet-training usually called 'potty' training. We attempt to answer the following questions. What influence on the development of bowel and bladder control do the age at the onset and frequency of daily potty training have? What is the importance of the child's own initiative, and to what extent can it be influenced by training?

SUBJECTS AND METHODS

From 1955 to 1976 a longitudinal study of growth and development of 413 healthy Swiss children was conducted at the Kinderspital Zurich, in co-operation with the Centre International de l'Enfance in Paris (Falkner (1960) These children form a representative selection of a Swiss urban population, according to the occupational status of the parents.

Before six months of age, data only on potty training were obtained. After that age, data on the different stages of the development of bowel and bladder control are available for 72 children at nine months, for 96 children at 12 months, for 163 children at 18 months and for 320 children at two years and thereafter. The children were seen at the ages of one, three, six, nine, 12, 18 and 24 months, and thereafter at yearly intervals.

The mothers reported the stage of bowel control and of bladder control by day and at night reached during the month before each examination. The following scoring system was used: 0 per cent = no control; 1 to 30 per cent = partial control during approximately one-third of the time; 30 to 70 per cent = control during one-third to two-thirds of the time; 70 to 95 per cent = total control except for a few relapses; and 100 per cent = total control. In addition, the mothers were asked how often they prompted the child to go on to the potty, and whether or not the child asked for the pot. (For further details, see Falkner (1960), in which the complete questionnaires have been published, and our report (Largo *et al.* 1977), in which the development of bowel and bladder control by day and at night is described in detail.)

In the present study, sex is not differentiated because of statistically insignificant differences.

RESULTS

Potty Training under 12 months

Onset of Potty Training and Development of Bowel and Bladder Control

Potty training was started in 3 per cent of the children in the first month and in 13 per cent by the third month of life. At six months 32 per cent, at 12 months 96 per cent and at two years all the children had been put on the pot (Largo *et al.* 1977).

The significance of the age at onset of potty training was investigated in two groups of children. Group A consisted of children whose training began between the frist and sixth month of life; group B consisted of children who were put on the pot for the first time between eight and 12 months. At the age of one year the children in group A showed a significantly higher stage of bowel control than those in group B, but at the age of 18 months there was no longer a difference between the two groups (Table 1). With regard to bladder control by day and at night, there was no significant difference between the two groups either at 12 or at 18 months. Thus, whether a child is put on the pot at the beginning or at the end of his first year, there is merely a short-term difference for bowel control and none at all for bladder control by day and at night.

Incidence of Daily Prompting

From 1½ to three years of age the percentage of children prompted not at all or less than once daily to go

* We acknowledge the authorization given by Spastics International Medical Publications to reproduce this paper appeared in Developmental Medicine and Child Neurology, 1977, 19, 607-613.

TABLE 1

Age at beginning of toilet-training in rlation to bowel/bladder control at 1 and 1

Bowel/bladder control	*Stage of control* 0%	1 – 30%	30 – 70%	70 – 95%	100%	
Bowel control						
At 1 year						
Group A* (n = 30)	1	1	3	9	16	$\chi^2 = 12.1$
Group B (n = 33)	7	5	5	10	6	$p < 0.05$
At 1½ years						
Group A (n = 51)	1	4	2	13	31	$\chi^2 = 5.0$
Group B (n = 49)	3	6	6	8	26	$p < 0.01$
Bladder control, day						
At 1 year						
Group A (n = 30)	20	2	4	4	–	$\chi^2 = 4.9$
Group B (n = 33)	24	3	6	–	–	$p < 0.1$
At 1½ years						
Group A (n = 51)	27	10	5	2	7	$\chi^2 = 4.9$
Group B (n = 49)	27	7	5	7	3	$p < 0.1$
Bladder control, night						
At 1 *year*						
Group A (n = 30)	28	2	–	–	–	$\chi^2 = 0.5$
Group B (n = 33)	32	1	–	–	–	$p < 0.1$
At 1½ years						
Group A (n = 51)	39	5	4	3	–	$\chi^2 = 4.4$
Group B (n = 49)	36	8	2	1	2	$p < 0.1$

*Group A: toilet-training started between 1 and 6 months of age.
Group B: toilet-training started between 8 and 12 months of age.

on the potty increased from 15 per cent to 75 per cent (Table 2). During the same period the proportion of children prompted more often than five times a day dropped from 45 to 3 per cent. In their fourth year, 94 per cent of the children were prompted not more than once or twice daily.

TABLE 2

Incidence of daily prompting

Promptings per day	*Age (yrs)* 1½	2	3	4
	%	%	%	%
0	4	2	9	33
< 1	10	24	66	36
1 – 2	21	17	14	25
3 – 5	20	23	8	5
< 5	45	34	3	1

Relationships Between Daily Prompting and Bowel Control and Daytime Bladder Control

Once bowel control and daytime bladder control are established the children do not need to be prompted frequently to remain clean and dry. Table 3 demonstrates that at age two years the majority of the children with complete bowel control or complete bladder control by day or at night were prompted not more than twice daily. On the other hand, frequent prompting may lead to complete bowel control, but has no influence on the development of complete bladder control by day and at night. At age three, children who were prompted more than five times a day may gain complete bowel control, but not complete bladder control by day or at night.

Significant relationships between frequency of daily prompting and stage of control are also found for bowel control at age 1½ and three years ($p < 0.01$), and for bladder control by day and at night at age three and four years ($p < 0.001$).

The long-term influence of daily prompting has been analyzed in children who had no bladder control by day or at night at age two (Table 4). At age three, children who were prompted more than five times a day at age two were more likely to have 70 to 95 per cent of blad-

TABLE 3

Daily prompting in relation to bowel/bladder control at age 2 years

Promptings per day	*Stage of control* 0%	1 – 30%	30 – 70%	70 – 95%	100%	
Bowel control						
0 – 2	4	0	4	0	122	χ^2 = 62.7
3 – 5	0	2	3	13	53	p < 0.001
< 5	0	12	6	24	59	(n = 302)
Bladder control, day						
0 – 2	6	0	7	80	36	χ^2 = 118.9
3 – 5	19	6	10	16	19	p < 0.001
< 5	30	26	22	18	7	(n = 302)
Bladder control, night						
0 – 2	34	15	20	44	17	χ^2 = 115.1
3 – 5	33	16	9	6	6	p < 0.001
< 5	90	6	5	0	0	(n = 301)

der control by day than those prompted less often at age two. However, there is no difference between the number of children 100 per cent dry in the group prompted more than in the group prompted less often. This means that only partial diurnal bladder control can be achieved by very frequent prompting. Bladder control at night is not influenced at all by frequent prompting, but neither can negative effects of frequent prompting be found.

The Child's Initiative

Incidence of Asking for Pot

At age one 5 per cent of all children asked for the pot, at age 1½ the proportion was 33 per cent, at age two 71 per cent and at age three 97 per cent.

Relationships Between Child's Initiative and Development of Bowel and Bladder Control

Table 5 shows that, at age two, children who asked for the pot were more likely to be clean and dry by day and at night than children who did not ask. The latter may have complete bowel control, but it is unlikely that they were dry by day and even less likely that they were dry at night.

These significant relationships between the child's initiative and the development of bowel and bladder control are equally valid for the ages of 1½ and three years ($p < 0.01$).

Influence of Daily Prompting on Child's Initiative

Table 6 shows that at age two, children who asked for the pot were prompted significantly less frequently than those who did not ask. The same relationship is also found at age 1½ and three years ($p < 0.005$).

Children who did not ask for the pot at 1½ years of age were investigated to see how far frequent prompting may influence the child's initiative (Table 7). There was no significant difference at two years between the children who had been prompted more than five times a day at 1½ years and those who had been prompted less often at that age. Thus, the child's initiative is not promoted by frequent prompting. On the other hand, neither can a negative influence of frequent prompting be proved.

DISCUSSION

Several authors have shown that earlier potting is likely to lead to earlier control by day and at night, with a smaller risk of relapses (Douglas and Blomfield 1958, Drillien 1959, Newson and Newson 1968). Klackenberg (1955, 1971) found that the age at which toilet-training began had no influence on the development of bladder control. Our data indicate that the development of bowel control and of bladder control by day and at night are influenced in different ways by toilet-training. The development of bowel control can be accelerated by early potting training (in the first six months of life) and frequent daily prompting (more than five times a day). The development of bladder control by day responds only partially to frequent prompting and not at all to early toilet-training. Finally, the development of bladder control at night cannot be influenced by either early potting or frequent prompting. The accelerating effects of potty training are very limited and do not justify early potting or a

TABLE 4

Daily promptings at age 2 in relation to bladder control at age 3 years in children not dry by day or at night at age 2 years

Promptings per day at age 2	*Stage of control at age 3*					
	0%	1 – 30%	30 – 70%	70 – 95%	100%	
Bladder control, day						
0 – 2	0	1	3	2	1	$\chi^2 = 15.4$
3 – 5	0	3	4	9	4	$p < 0.05$
< 5	1	0	2	25	5	(n = 60)
Bladder, control, night						
0 – 2	1	4	6	17	6	$\chi^2 = 4.3$
3 – 5	3	2	2	19	7	$p < 0.1$
< 5	4	10	11	49	17	(n = 158)

TABLE 5

Asking for the pot in relation to bowel/bladder control at age 2 years

Asking for pot	*Stage of control*					
	0%	1 – 30%	30 – 70%	70 – 95%	100%	
Bowel control						
+ (n = 213)	5	3	5	15	185	$\chi^2 = 43.6$
– (n = 90)	0	9	5	25	51	$p < 0.001$
Bladder control, day						
+ (n = 213)	21	12	22	104	54	$\chi^2 = 75.0$
– (n = 90)	36	17	17	14	6	$p < 0.001$
Bladder control, night						
+ (n = 213)	81	28	34	47	23	$\chi^2 = 57.3$
– (n = 90)	75	9	4	1	1	$p < 0.001$

high daily frequency of potting. On the other hand, we have not found any negative consequences of an early beginning and very intensive potty training, such as delayed development of bowel and bladder control or more relapses in the following years (Largo, to be published). This is important, as one often hears that enuretic children's toilet-training frequently was begun very early.

Five per cent at age one, 71 per cent at age two and 95 per cent of our children at age three ask for the pot. Similar findings in children 2½ years old are reported by Roberts and Schoellkopf (1951). Our data demonstrate that this personal initiative of the child is a part of the maturation process of bowel and bladder control, and is not dependent on training. Children who ask for the pot are far more likely to be clean and dry than those who do not. The latter children may be capable of voiding their bowels into the pot, but can hardly be dry by day, and not at all at night. Furthermore, frequent prompting by the mother does not induce more initiative in the child.

TABLE 6

Daily prompting in relation to asking for the pot at age 2 years

Prompting per day	*Asking*	*Not asking*	
	No.	*No.*	
0 – 2	132	2	$\chi^2 = 154.7$
3 – 5	56	14	$p < 0.001$
< 5	19	68	(n = 391)

TABLE 7

Daily prompting at age 1½ in relation to asking for the pot at age 2 in children not asking for the pot at age 1½ years

Prompting per day at age 1½	*At age 2*		
	Asking	*Not asking*	
	No.	*No.*	
0 – 2	21	5	$\chi^2 = 1.4$
3 – 5	22	5	$p < 0.1$
< 5	29	12	(n = 94)

In respect to onset and frequency of daily prompting, toilet-training is not successful as a conditioning process in the first years of life. We believe that potty training should consist of no more than offering the child the possibility of using the pot when the maturation process of bowel control and, at a later age, of bladder control, is completed. A reliable indicator that the child is developmentally able to be clean and dry is his awareness of soiled and wet pants and his asking for the pot.

Acknowledgement: We thank St. Teplin and C. Trowbridge, Department of Pediatrics, University of California, Los Angeles, for their help in the preparation of the manuscript.

AUTHORS' APPOINTMENTS

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SUMMARY

The rôle of potty training and the child's own initiative to use the pot were evaluated in 320 Swiss children in the Zurich longitudinal study (1955-1976). Initiating potty training in the first months of life has a short-term effect on bowel control, but no effect on bladder control by day or at night. Frequent daily prompting to use the pot results in a higher percentage of completely bowel-trained children, and of children partially but not completely dry during the day. It has no influence on bladder control at night.

Asking for the pot is part of the maturation process of bladder control. A child who does not ask for the pot may not soil himself but is unlikely to be dry by day nor, especially, by night. The child's asking for the pot cannot be induced by frequent prompting.

RÉSUMÉ

Le rôle de l'apprentissage du pot et de l'initiative de l'enfant a été apprécié chez 320 jeunes enfants suisses au cours d'une étude longitudinale de croissance et de développement menée à Zurich de 1955 à 1976. Les résultats ont montré qu'un apprentissage du pot débuté durant les premiers mois de la vie a un effet à court terme sur le contrôle rectal, mais aucun effet sur le contrôle vésical ni de jour, ni de nuit. Des incitations journalières permettent un pourcentage plus élevé d'enfants complètement éduqués sur le plan rectal et d'enfants partiellement mais non complètement secs durant le jour. Il n'y a aucune influence sur le contrôle vésical de nuit.

Réclamer le pot appartient au processus de maturation du contrôle vésical. Un enfant qui ne demande pas le pot peut ne pas se souiller mais il est très rare qu'il soit sec durant le jour et il est presque certainement mouillé la nuit. Un enfant ne peut être poussé à demander le pot par de fréquentes incitations.

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Analysis of the adolescent growth spurt using smoothing spline function *

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INTRODUCTION

The analysis of longitudinal growth data usually consists of two steps: first, parameters have to be defined which summarize the important properties of the growth process; second, a method has to be found which assigns to each individual series of measurements the corresponding set of parameter values. The distribution of these parameters over the sample can then be analysed by classical statistical procedures.

Hitherto, the commonly used method to perform the first step was to choose a parametric family of curves and to ascertain the parameter values for each individual by the method of least squares. However, prepubertal growth is completely different from pubertal growth, and the pubertal component shows features with a high variability over the population. This makes it difficult to find a parametric family of curves which meets the following two requirements: (*a*) it should fit all individual series of measurements without systematic errors; (*b*) its parameters should summarize those properties of the curve in which one is interested.

In view of requirement (*a*), most authors (Deming, 1957; Marubini, Resele and Barghini, 1971: Marubini, Tanner and Whitehouse, 1972; Tanner, Whitehouse, Marubini and Resele, 1976) restrict themselves to a description of the growth spurt. Bock, Wainer, Petersen, Thissen, Murray and Roche (1973) use the superposition of two logistic functions to describe both the prepubertal and the pubertal period. However, their family of curves does not meet requirement (*a*). An average squared residual of 2.0 cm^2 in girls indicates a clear lack of fit. As far as requirement (*b*) is concerned, the parameters of the logistic function accounting for prepubertal growth vary greatly between sexes. This indicates that they do not summarize the properties of growth in early childhood very well. Prepubertal growth is known to be almost the same for both sexes.

In our study, the methodological approach is different. We estimate the individual curves of growth velocity non-parametrically, using smoothing spline functions. Parameters such as peak height velocity and age at peak height velocity are then calculated directly from the estimated individual curves. With the help of these parameters, the variability over the population and sex differences in the growth spurt are described. In a further analysis of prepubertal and pubertal growth, the parameters are presented as linear functions of four independent factors and the relationships between the parameters are evaluated.

SUBJECTS AND METHODS

Subjects

In 1955 a prospective longitudinal study of growth and development of 412 healthy Swiss children was initiated at the Kinderspital Zurich and is still in progress. The work is being done in coordination with four other longitudinal growth studies in Europe (Brussels, London, Paris and Stockholm), and the Centre International de l'Enfance (CIE) in Paris. In the present work, data of 112 boys and 110 girls are included. In none of these children were more than three measurements or two consecutive measurements missing between 4 and 18 years. No child was suffering from a disease which might have hampered growth. Six boys and two girls of very tall stature were treated with high doses of sex hormones in order to reduce predicted adult height and were therefore excluded from the study.

Measurements

Height was measured according to the direction of the CIE (Falkner, 1960), using gentle upward pressure under the mastoid process. After the age of 8 years all measurements were done by the same trained anthropometrist (Miss M. Willisegger). Before the age of 9 years in girls and 10 years in boys the children were measured yearly at birthday ± 14 days. Afterwards they were measured 6-monthly within the same limits until the annual increment in height was less than 0.5 cm/year. Thereafter, the measurements were done again annually and were discontinued when the increment had become less than 0.5 cm in 2 years.

Editing

Gross errors were looked for by searching for negative increments in height and by visual inspection of the raw and smoothed velocity curves on the computer display. The few which could not be corrected with the help of the original sheets were treated as missing data. Missing observations were completed using an iterative procedure which assured that the filled-in pseudo-observations had zero residuals when the series of

* This paper first appeared in Ann. Hum. Biol. (published by Taylor and Francis Ltd, London), 1978, 5, 421-434.

height measurements was smoothed. Results of cross-validation (Whaba and Wold, 1975) and visual comparison of measured velocities with simulated velocities, where the variance of the "random" errors was known, suggest that the "random" fluctuations in height measurements have a standard deviation of about 4 mm.

All computations were performed on the CDC 6400/6500 of the Computer Centre of the Swiss Federal Institute of Technology (ETH), Zurich. For the graphical output a Textronix 4014 display and a Benson plotter were used.

Methods

(*a*) *Smoothing spline functions.* For detailed description of the statistical methods and the algorithms used, see Stuetzle (1977). Since the methods are quite important with respect to the present findings, a qualitative explanations follows.

In any statistical analysis of longitudinal data, one tries to determine those traits in the individual curves which are consistent over the population, and to disregard the superposed fluctuations which stem from the histories of single individuals and are not related to the growth process per se. This leads to the following decomposition:

$$f_j(t_i) = f_j^*(t_i) + e_j(t_i),$$

where f_j = series of measurements at times t_i, f_j^* = unknown growth pattern of individual j, and e_j = random term, including measurement error.

We would like to estimate f_j^* as accurately as possible. There exist two different approaches, the regression and the smoothing method, both with specific advantages and disadvantages.

The regression method postulates one functional form for the growth process over a certain epoch for all individuals; e.g. the logistic function (Marubini *et al.*, 1971)

$$f^*(t) = a/\{1 + \exp[-b(t - c)]\}$$

or the Gompertz function (Deming, 1957), both of which are used for fitting height measurements:

$$f^*(t) = a \exp\{-\exp[-b(t - c)]\}$$

For each individual, parameters a, b, and c are estimated by least squares. The above functions are no more than a clever guess, and a serious bias may result due to the differences between the estimated curve and the real growth process. A residual analysis on individuals, e.g. by a run test, is not likely to reveal a distinct bias over the population; this is due to the low discrimination power for small sample size. The introduction of regression functions with more parameters may lower the bias, but at the price of higher variability of the estimated parameters.

The smoothing approach does not assume a unique form of the growth process for all individuals, and we need not postulate a functional form. A graphical procedure, as used in Tanner *et al.* (1966), may be biased and is only reproducible in skilled hands. We estimate f_j^* by cubic smoothing spline functions (Reinsch, 1967). Such a function (s) allows for an arbitrary squared deviation C from the measured values:

$$\Sigma_i [s(t_i) - f(t_i)]^2 \leq C$$

and in addition has to be made as smooth as possible:

$$\int s''(t)^2 \, dt = \min!$$

Mathematics can prove that s consists piecewise of cubic polynomials, and that the pieces are pasted together very smoothly (with continuous first and second order derivatives). Two extreme cases illustrate how the choice of the smoothing constant C influences the shape of the estimated curve:
(1) $C = 0$: s passes through the measurements $(t_i, f(t_i))$
(2) $C = \infty$: s becomes the least squares straight line

The crucial point of any smoothing method lies in the choice of the smoothing constant C. Too large a C may introduce an intolerable bias, and with C too low, we are faced with a large variability. The optimal C makes a compromise between bias and variability. The bias problem here is more transparent than in regression since the smoothing procedure tends to flatten the peaks and fill-up the troughs.

Instead of using common trial-and-error approach, the constant C has been determined by cross-validation (Wahba and Wold, 1975) for each individual. This "one-hold-out" technique has been successful, judged both by eye for the real data and by statistical criteria in simulation. The smoothing approach is excellent, as long as we remain with descriptive processes; for real modelling, parametric methods become necessary and fruitful, as will be demonstrated in a forthcoming paper (Stuetzle, Gasser, Largo, Prader and Huber, in the press).

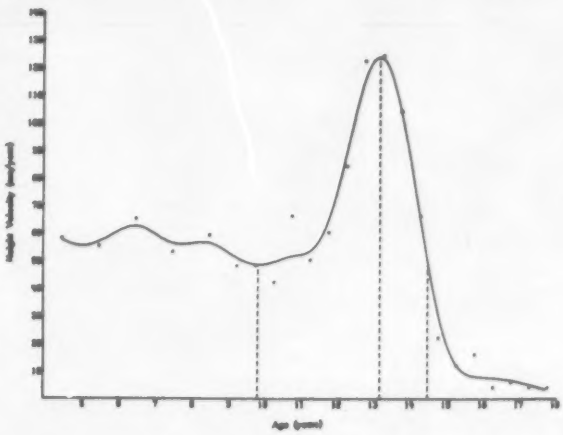

Fig. 1 Raw height velocities (divided differences of measured heights) and estimated height velocity curve of a boy who had one of the most prominent growth spurts.

Hitherto, growth curves have been analysed using series of measurements of height attained. In this study, the smoothing spline functions are applied to series of values of height velocity. Velocity curves may present more difficulties with regard to estimation and interpretation than distance curves because of large stochastic variations (which are inversely related to the time intervals between the measurements). But the growth process which velocity curves offer. Unequal variance and the correlation structure, introduced by forming velocities, can both be accounted for in spline computations. In the case of growth velocity curves we expect the largest bias at the age at this point can be estimated by the following procedure:

(*a*) For each individual the residuals (differences between measurements and estimated curve) are determined.

(*b*) The individual curves and the residuals are shifted on the time scale until all the APHV coincide.

(*c*) The residuals are smoothed by a moving average.

The maximal mean residual in our sample was about 5 mm/yr.

The same idea of alignment is used by Tanner *et al.* (1966) to construct their individual type standards.

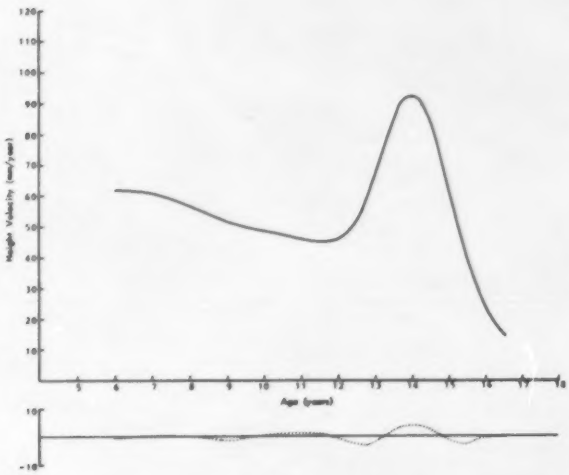

Fig. 2 50th percentile of height velocity in boys (peak height centred). At the bottom mean smoothed bias curve (see methods, section (*c*).

(*b*) *Definition of the parameters* (*Figure 3 and Table 1*)

Prepubertal height velocity (PV) is defined as the mean annual increment between age 4 and 6½ years. This age period was chosen because during this period there were no major changes in height velocity, especially those due to the onset of pubertal growth. Minimal pre-spurt height velocity (MHV) signifies the onset of the growth spurt age at minimal pre-spurt height velocity (AMHV) denotes the age at which the spurt begins. Peak height velocity (PHV) is defined as the maximum height velocity during the growth spurt and age at peak height velocity (APHV) as the age at which PHV occurs. Peak height (PH), or increase in height velocity during the growth spurt, is defined as the difference between peak height velocity (PHV) and minimal pre-spurt height velocity (MHV). Minimal pre-spurt height velocity return (MHVR) and age at minimal pre-spurt height velocity return (AMHVR) age height velocity and age when after the spurt, MHV is again attained. AMHVR defines—somewhat arbitrarily—the end of the spurt and is a measure for the duration of growth. Peak basis (PB) is defined as AMHVR – AMHV and is a measure for the duration of the spurt. Peak area (PAR) is defined as PX × PB and is a measure for the intensity of the spurt.

H4 is height at age 4. HMHV, HPHV and HMHVR are defined as height at the onset, at the peak and at the end of the growth spurt. HA (adult height) is defined in 57 boys and 78 girls as the height measured after a 2-year period with an increment in height of less than 0.5 cm. In the other 55 boys and 32 girls who have not yet reached that stage at 20 years of age HA represents height at the age of 20 years.

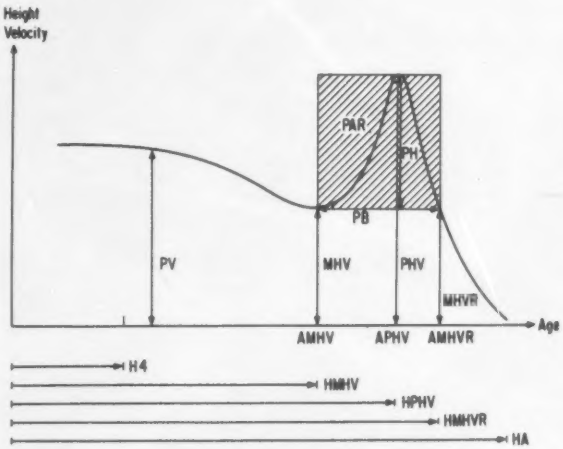

Fig. 3 Definition of the parameters.

RESULTS

General description of the adolescent spurt (Table 1 and Figure 4)

From 4 to 9½ years there is only a slight difference in height velocity between boys and girls. The adolescent spurt starts in girls at a mean age of 9.6 years, ranging from 6.6 to 12.9 years (AMHV). In boys the spurt begins 1.4 years later than in girls, at a mean age of 11.0 years, with the earliest onset at 7.8 years and the latest at 13.5 years. As the peak curve has an asymmetrical shape, the peak height velocity (PHV) is attained only at the beginning of the third part of the

TABLE 1

Means, SD and range of the parameters

Parameters		Sex	Mean	SD	Range
AMHV	Age at minimal prespurt height velocity (yr)	m	11.0	1.2	7.8 – 13.5
		f	9.6	1.1	6.6 – 12.9
APHV	Age at peak height velocity (yr)	m	13.9	0.8	12.0 – 15.8
		f	12.2	1.0	9.3 – 15.0
AMHVR	Age at minimal prespurt height velocity return (yr)	m	15.5	0.9	13.5 – 17.4
		f	13.5	1.1	10.0 – 16.2
H4	Height at age 4 (cm)	m	104.3	3.7	96.3 – 114.0
		f	103.1	3.7	93.4 – 111.9
HMHV	Height at minimal prespurt height velocity (cm)	m	143.8	7.7	122.7 – 164.9
		f	135.8	7.3	112.2 – 151.0
HPHV	Height at peak height velocity (cm)	m	161.9	6.2	149.3 – 177.5
		f	150.5	5.7	135.9 – 161.8
HMHVR	Height at minimal prespurt height velocity return (cm)	m	173.0	5.9	161.4 – 187.6
		f	159.0	5.6	144.9 – 170.7
HA	Adult height (cm)	m	177.4	6.2	165.8 – 193.5
		f	164.8	5.7	149.8 – 176.6
PV	Prepubertal height velocity at age 4-6½ (cm/year)	m	6.3	0.6	4.9 – 8.1
		f	6.3	0.6	4.8 – 8.1
MHV	Minimal prespurt height velocity (cm/yr)	m	4.2	0.6	2.9 – 6.0
		f	4.8	0.7	3.0 – 7.0
PHV	Peak height velocity (cm/yr)	m	9.0	1.1	6.7 – 12.4
		f	7.1	1.0	5.0 – 10.1
PH	Peak height (cm/yr)	m	4.8	1.3	1.9 – 7.7
		f	2.4	1.0	0.7 – 5.6
PB	Peak basis (yr)	m	4.5	0.9	2.6 – 8.2
		f	3.9	0.8	1.3 – 6.5
PAR	Peak area = PH × PB (cm)	m	21.7	6.8	8.2 – 53.2
		f	9.4	4.5	0.1 – 25.2

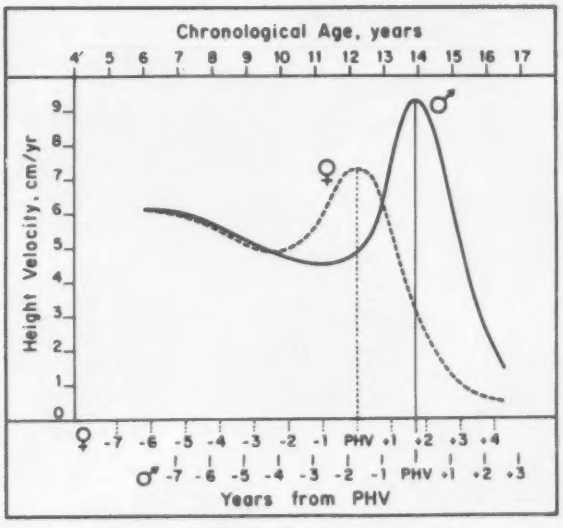
Chronological Age, years
4 5 6 7 8 9 10 11 12 13 14 15 16 17
Height Velocity, cm/yr
0 1 2 3 4 5 6 7 8 9
♀ -7 -6 -5 -4 -3 -2 -1 PHV +1 +2 +3 +4
♂ -7 -6 -5 -4 -3 -2 -1 PHV +1 +2 +3
Years from PHV

Fig. 4 50th percentile of height velocity in boys and girls (peak height centred).

peak, that is, at 12.2 years in girls and at 13.9 years in boys (APHV). Peak height (PH), or increase in height velocity during the growth spurt, in boys is 4.8 cm/year, which is twice as high as in girls. Peak height velocity (PHV), the sum of the minimal pre-spurt height velocity (MHV) and the peak height (PH), averages 9.0 cm/year in boys and 7.1 cm/year in girls. The end of the adolescent spurt (AMHVR), defined as the age when the minimal prepubertal velocity (MHVR) is again attained, is reached 3.8 years after the onset of the spurt in girls and 4.5 years thereafter in boys.

The adult height (HA) is 177.4 cm in boys and 164.8 cm in girls. Adult height is midly underestimated for two reasons. Firstly, according to our definition of adult height (see methods), growth ceased only in two thirds of the girls and in half of the boys at 20 years of age. Secondly, the exclusion from the study of six boys and two girls of very tall stature decreases the mean adult height by about 8 mm in boys and 2 mm in girls.

Variations in the adolescent spurt (Table 1 and Figure 5)

The age at peak velocity (APHV) averages 12.2 years in girls and 13.9 years in boys and has wide range of 5.7

years or 3.8 years respectively. The peak basis (PB), which is a measure of the duration of the growth spurt, may be as short as 1.3 years in girls or 2.6 years in boys and may reach 6.5 years or 8.2 years respectively. In 2% of the boys and 33% of the girls, the peak height (PH) is less than 2 cm/year (Figure 5). A peak height of at least 4 cm/year, or in terms of peak height velocity (PHV), a doubling of the minimal pre-spurt velocity (MHV), is found in 70% of the boys and only 11% of the girls. A peak height higher than 6 cm/year is observed in 17% of the boys and in none of the girls.

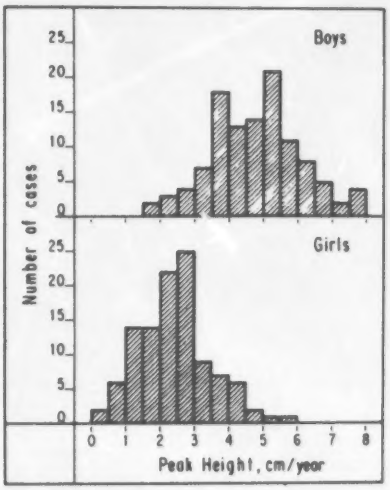

Fig. 5 Histograms of peak height in boys and girls.

TABLE 2

Sex difference

		Height (cm)	% of HA	Sex difference (cm)
H4	f	103.1	62.6	
	m	104.3	58.8	1.2
HMHV	f	135.8	82.4	
H (AMHV – 1.4 yr)	m	137.4	77.5	1.6
HMHV	m	143.8	81.1	8.0
HPHV	f	150.5	91.3	
	m	161.9	91.3	11.4
HMHVR	f	159.0	96.5	
	m	173.0	97.5	14.0
HA	f	164.8	100.0	
	m	177.4	100.0	12.6

Adolescent spurt and sex differences in adult height (Table 2)

At ate 4 the boys are 1.2 cm taller than the girls. The difference between the height of the girls at the onset of their spurt (AMHV) and the height of the boys at the corresponding age, namely 1.4 years before the onset of the boys' spurt (height at (AMHV minus 1.4 years)) is 1.6 cm. The sex difference in height at the age of minimal pre-spurt height velocity (AMHV) is 8.0 cm; at age of peak height velocity (APHV) it is 11.4 cm; at the end of the adolescent spurt, defined as the age when minimal pre-spurt height velocity is again attained (AMHVR), it is 14.0 cm. After the adolescent spurt, the sex difference drops to 12.6 cm at the age when growth has ceased. Thus the sex difference of 12.6 cm in adult height is composed of the following four components: + 1.6 cm caused by the more extensive growth in boys during the prepubertal period, + 6.4 cm by the more extensive growth of the girls in the post-spurt period.

To further clarify the sex difference in height growth it is interesting to look at the percentages of adult height attained at different ages. At the girls' onset of the adolescent spurt (AMHV), 82.4% of the adult height is attained by girls; in boys, only 77.5% of the adult height is attained. Because of the delay in spurt, the boys have a lower percentage of adult height than girls at the same chronological prepubertal ages. So, at the age of 4, girls have attained 62.6% and boys 58.8% of the adult height. At the onset of the spurt (AMHV) in both sexes the percentage of adult height attained is 82.4% for girls and 81.1% for boys. At the end of the spurt, the boys have reached 97.7% and the girls 96.5%. This confirms that the adolescent spurt in boys contributes more to the adult height than it does in girls, whereas in the post-spurt period the contribution to adult height in girls is larger than in boys. The latter finding may be in part due to the fact that two thirds of the girls, but only half of the boys have attained adult height according to our definition.

Using only peak height (PH) and age at peak height velocity (APHV) in discriminant analysis, 90% of the individuals could be classified correctly by sex. If all derived parameters were used, this was possible in 97% of the children.

Relationships between the different parameters (Figure 6, Table 3 and 4)

A factor analysis yielded 4 independent factors (only the results for boys are given, the pattern in girls is the same). These factors reflect the parameters in linear combinations and explain about 90% of the variance in the 14-dimensional factor space. After appropriate rotation (Quartimax) the factors may be interpreted as follows: factor 1 is height (essentially identical with adult height); factor 2 is duration of growth (essentially identical with AMHVR); factor 3 is peak height (PH), and factor 4 is peak basis (PB). Figure 6 and Table 3 illustrate that adult height (HA ~ f1) is uncorrelated with the timing (AMHV, APHV, AMHVR ~ f2), the

TABLE 3

Correlations between parameters

BOYS

	AMHV	APHV	AMHVR	H4	HMHV	HPHV	HMHVR	HA	PV	MHV	PHV	PH	PB	PAR
AMHV		0.65 ***	0.62 ***	−0.08	0.64 ***	0.20 *	0.15	0.09	−0.26 **	−0.34 ***	−0.11	0.06	−0.67 ***	−0.40 ***
APHV	0.80 ***		0.96 ***	−0.20 *	0.24 *	0.22 *	0.13	0.04	−0.32 ***	−0.48 ***	−0.36 ***	0.09	0.09	−0.04
AMHVR	0.73 ***	0.97 ***		−0.27 **	0.14	0.11	0.08	−0.01	−0.37 ***	−0.59 ***	−0.37 ***	−0.04	0.17	0.06
H4	−0.03	−0.25 **	−0.30 ***		0.63 ***	0.78 ***	0.77 ***	0.78 ***	0.47 ***	0.37 ***	−0.01	−0.19	−0.15	−0.25
HMHV	0.67 ***	0.28 **	0.16	0.63 ***		0.81 ***	0.76 ***	0.74 ***	0.36 ***	0.17	−0.04	−0.12	−0.66 ***	−0.54 ***
HPHV	0.48 ***	0.33 ***	0.25 **	0.66 ***	0.87 ***		0.96 ***	0.95 ***	0.52 ***	0.35 ***	−0.04	−0.20 *	−0.15	−0.28 **
HMHVR	0.42 ***	0.33 ***	0.31 ***	0.59 ***	0.75 ***	0.95 ***		0.98 ***	0.51 ***	0.32 ***	0.09	−0.07	−0.12	−0.15
HA	0.22 *	0.05	0.01	0.71 ***	0.73 ***	0.88 ***	0.89 ***		0.54 ***	0.40 ***	0.11	−0.09	−0.12	−0.17
PV	−0.14	−0.42 ***	−0.50 ***	0.42 ***	0.46 ***	0.43 ***	0.32 ***	0.47 ***		0.37 ***	0.02	−0.16	−0.02	−0.16
MHV	−0.54 ***	−0.72 ***	−0.78 ***	0.30 ***	0.04	0.12	0.07	0.32 ***	0.57 ***		−0.01	−0.48 ***	−0.13	−0.48 ***
PHV	−0.30 ***	−0.36 ***	−0.30 ***	0.03	−0.13	0.04	0.22 *	0.18	0.01	0.39 ***		0.88 ***	−0.21 *	0.58 ***
PH	0.10	0.17	0.28 ***	−0.20 *	−0.16	−0.04	0.17	−0.05	−0.42 ***	−0.35 ***	0.73 ***		−0.12	0.74 ***
PB	−0.29 **	0.32 ***	0.45 ***	−0.39 ***	−0.64 ***	−0.29 **	−0.11	−0.27 **	−0.51 ***	−0.40 ***	−0.03	0.26 **		0.56 ***
PAR	−0.04	0.24 *	0.38 ***	−0.30 ***	−0.39 ***	−0.18	0.07	−0.14	−0.56 ***	−0.45 ***	0.57 ***	0.91 ***	0.59 ***	

GIRLS

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$.

TABLE 4

Conditional correlations given adult height (in boys).

		H4	PV	MHV	PH	PB
AMHV	m	−0.25 **	−0.37 ***	−0.41 ***		
	f	−0.26 **	−0.28 **	−0.65 ***		
APHV	m	−038 ***	−0.40 ***	−0.54 ***		
	f	−0.40 ***	−0.50 ***	−0.78 ***		
AMHVR	m	−0.43 ***	−0.43 ***	−0.64 ***		
	f	−0.44 ***	−0.57 ***	−0.83 ***		
HMHV	m				−0.08	−0.85
	f				−0.19 *	−0.67 ***

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$.

height (PH ~ f3), the duration (PB ~ f4) and the intensity (PAR) of the spurt. Minimal pre-spurt height velocity (MHV) and peak height velocity (PHV) are both negatively correlated with age; in remarkable contrast, peak height (PH) is independent of height and age.

A negative partial correlation given adult height was found between the age of minimal prepubertal height velocity (AMHV) and the height at age 4 (H4), and between the prepubertal height velocity (PV) and the age at the onset of the spurt (AMHV) (Table 4). The same applies to the age at peak height velocity (APHV) and the age at the end of the spurt. (AMHVR). Further there is a negative partial correlation given adult height between the height at the onset of the spurt (HMHV) and the peak basis (PB), a measure for the duration of the spurt, but there is no significant correlation between HMHV and peak height (PH).

DISCUSSION

In this study, the onset of the adolescent growth spurt, defined as the age of minimal pre-spurt height

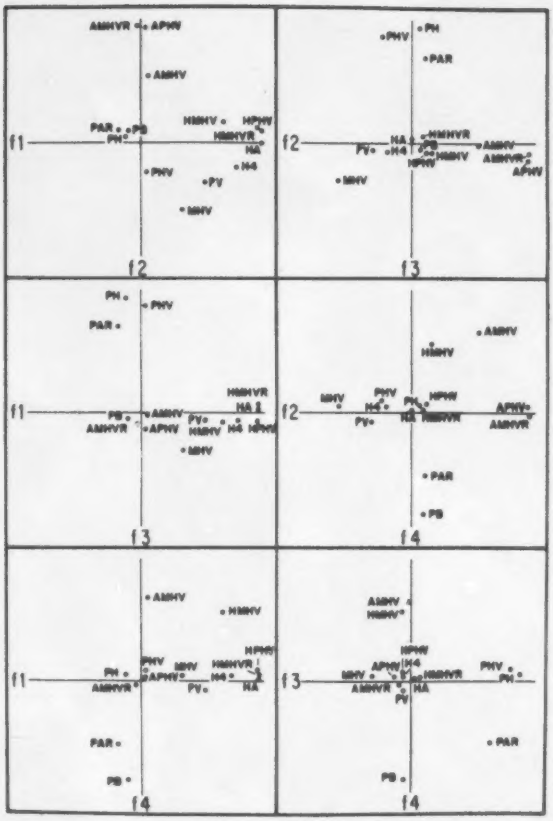

Fig. 6 Factor analysis in boys. The four factors represent adult height, duration of growth, peak height and peak basis.

velocity (AMHV), is 11.0 years in boys and 9.6 years in girls. Thus the onset of the pubertal growth spurt is slightly earlier than the appearance of the first sex characteristics and the clinically discernible growth spurt.

In our children, the spurt starts about 1.0 year earlier in boys and 0.7 year earlier in girls than in the Harpenden study (Tanner *et al.*, 1976). The reason for this difference may be that the age of minimal pre-spurt height velocity (AMHV) cannot be discerned accurately by fitting logistic curves to the growth spurt, but can only be estimated by eye as done by Tanner *et al.* (1976). However, it cannot be ruled out that our smoothing procedure may have slightly underestimated the age at which the spurt takes off. As a consequence of the earlier onset of the spurt, all our parameters which depend on AMHV are somewhat different from those of the Harpenden study. The height at the onset of the spurt (HMHV) is 2.3 cm smaller in boys and 2.1 cm smaller in girls than in the Harpenden study. The adolescent gain in our children, defined as adult height minus height at minimal prespurt height velocity, is 33.6 cm in boys and 29.0 cm in girls. This is 6.0 cm more, and 3.8 cm more respectively than in the Harpenden study. In addition to the earlier onset of the spurt this difference is a reflection of the greater adult height of 177.4 cm in boys and 164.8 cm in girls in our study.

In the analysis of the derived parameters, we were mainly interested in the following three questions: (1) How large is the individual variation in the adolescent spurt? (2) Which aspects of the growth spurt best characterize sex differences, and how do these relate to the sex difference in adult height? (3) Which parameters best define the adolescent spurt and what are the relationships between these parameters?

Besides the well-known wide variation in the age of the adolescent spurt, our data demonstrate that there is also a great variation in the duration and height of the peak. The peak basis, as a mesure of the duration of the adolescent spurt, may be as short as 1.3 years in girls and 2.6 years in boys or may exceed 6 and 8 years respectively. Peak height, or the increase in height velocity during the growth spurt, may be as small 0.7 cm/year in girls and 1.9 cm/year in boys or may be as large as 5.6 and 7.7 cm/year respectively.

In agreement with Deming (1957) and Tanner *et al.* (1976), our data show that the pubertal growth spurt is much more impressive in boys than in girls. A peak height of at least 4 cm/year, which means, in terms of peak height velocity (PHV), a doubling of the minimal pre-spurt velocity, is found in 70% of the boys and in only 11% of the girls.

According to Tanner *et al.* (1962, 1976) the adult sex difference in height is due to the later onset rather than to the more extensive spurt in boys. We found that the longer lasting prepubertal growth and the greater extent of the growth spurt in males both contribute 6 cm to the final sex difference in adult height. Furthermore, during the post-spurt period the girls show a larger gain in height than the boys. Thus, the maximum sex difference of 14 cm at the end of the spurt is reduced to the final difference in adult height of 12.6 cm.

This analysis of the contribution of the growth spurt to the sex difference in adult height can be confirmed by looking at the percentage of adult height attained at different ages. During the prepubertal period the boys have a lower percentage of adult height than the girls at the same chronological age. At the age of peak height velocity, both sexes have reached 91.3% of the adult height and at the end of the spurt the boys have reached 97.5% and the girls 96.5% of their respective adult heights. Thus, in boys the prepubertal period required to attain the same percentage of adult height is longer; there is more growth during the pubertal period and less in the post-spurt period than observed in girls. These findings coincide with the fact that in discriminant analysis peak height (PH) and age at peak height velocity (APHV) allow a good discrimination between boys and girls.

Correlations indicate that adult height does not depend either on the duration of growth or on the dura-

tion and height of the peakl. Thus, a child does not become tall because of the late onset of a long lasting and high growth spurt. Furthermore, peak height, or increase in height velocity during the growth spurt, is independent of age and height of the child.

Partial correlations given adult height revealed two compensating mechanisms between the prepubertal and pubertal period. Firstly, a child with long-lasting growth, i.e. with a late growth spurt, tends to grow slower in the prepubertal period with respect to his adult height. Secondly, a child with a low prepubertal percentage of adult height has a longer-lasting but not higher spurt than a child with a higher prepubertal percentage of adult height.

Acknowledgments

We are grateful to Miss Willisegger who for the last 13 years has been the unfailing secretary and anthropometrist of our study. W. Stuetzle was supported in part by the Fritz Hoffmann La Roche Foundation.

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SUMMARY

Height growth velocity curves between 4.5 and 17.75 years were estimated, using smoothing spline functions, for 112 boys and 110 girls from the Zurich Longitudinal Study (1955-1976). Parameters characterizing the growth process, such as peak height velocity and age at peak height velocity, were calculated directly from the estimated curves.

The variability of parameters describing the adolescent growth spurt is large, both between and within sexes. Peak height, defined as increase of height velocity during the growth spurt, and age at peak height velocity both characterize the sex difference in growth in a highly significant manner. Peak height of at least 4 cm/year is found in 70% of the boys, but in only 11% of the girls. The age at peak height velocity averages 12.2 years in girls and 13.9 years in boys and has a wide range of 5.7 years and 3.8 years respectively.

The sex difference in adult height of 12.6 cm is composed of the following 4 factors: + 1.6 cm caused by more prepubertal growth in boys, + 6.4 cm by the boys' delay in spurt, + 6.0 cm by the more extensive spurt in boys and − 1.4 cm by more post-spurt growth in girls.

Correlations between parameters indicate that the adult height depends neither on the duration of growth, nor on the duration and height of the peak. Minimal pre-spurt height velocity and peak height velocity, but not peak height, are age- and height-dependent.

Partial correlations given adult height reveal two compensating mechanisms between growth in the prepubertal and in the pubertal period. Small prepubertal height and low height velocity with respect to adult height are followed by a late adolescent spurt and vice versa. Small height at the onset of the spurt with respect to adult height is followed by a longer lasting, but not higher spurt and vice versa.

RÉSUMÉ

Des courbes de vitesse de croissance en taille de 4,5 à 17,75 ans ont été estimées à l'aide de fonction de lissage des irrégularités pour 112 garçons et 110 filles de l'Etude Longitudinale de Zurich (1955-1976). Des paramètres caractérisent le processus de croissance, tels que le pic de vitesse de croissance en taille et l'âge à ce pic, ont été calculés directement à partir des courbes.

La variabilité des paramètres décrivant la poussée de croissance à l'adolescence est grande, à la fois entre les sexes et dans chaque sexe. La hauteur du pic, définie comme l'augmentation de la vitesse de croissance en taille durant la poussée de croissance, et l'âge au pic de croissance en taille caractérisent tous deux la différence sexuelle de croissance de façon hautement significative. Une hauteur du pic d'au moins 4 cm par an est trouvée chez 70% des garçons, mais chez seulement 11% des filles. L'âge au pic de vitesse de la taille est en moyenne de 12,2 ans chez les filles et 13,9 ans chez les garçons avec une large amplitude de 5,7 ans et 3,8 ans respectivement.

La différence sexuelle de taille adulte, de 12,6 cm, est composée des quatre facteurs suivants: + 1,6 cm causé par plus de croissance prépubertaire chez les garçons, + 6,4 cm par le retard des garçons en poussée pubertaire, + 0,6 cm par la poussée plus intense chez les garçons, et − 1,4 cm par davantage de croissance après la poussée chez les filles.

Les corrélations entre les paramètres indiquent que la taille adulte ne dépend ni de la durée de la croissance ni de la durée et de la hauteur du pic. La vitesse de croissance minimale avant la poussée et la vitesse de pointe, mais non la hauteur du pic, dépendent de l'âge et de la taille.

Les corrélations partielles à la taille adulte constante révèlent deux mécanismes compensatoires entre la croissance à la période prépubertaire et à la période pubertaire. Une petite taille prépubertaire et une basse vitesse de croissance en taille par rapport à la taille adulte sont suivies par une poussée pubertaire tardive et vice versa. Une taille petite au début de la poussée par rapport à la taille adulte est suivie par une poussée durant plus longtemps, mais plus intense, et vice versa.

Description des équipes et statut actuel des activités
Description of the teams and their present status

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— Le Ministère de la Santé Publique
— Le Ministère de l'Education Nationale
— Le Fonds de la Recherche Scientifique Médicale
— L'OTAN

Depuis le 31 décembre 1977, le Centre ne reçoit plus aucun subside.

Evolution de l'échantillon

L'échantillon original comptait 263 enfants nés à St-Gilles entre 1955 et 1958. Parmi eux, des jumeaux (une paire) et un enfant prématuré ont été écartés. Par la suite un enfant est décédé. L'échantillon proprement dit comportait donc 259 enfants.

Les examens ont eu lieu tous les trois mois jusqu'à l'âge de un an; les enfants ont été revus à 18 mois, ensuite à chaque anniversaire jusqu'à l'âge de 15 ans inclus. Des restrictions budgétaires n'ont pas permis de renouveler les examens à 16 et 17 ans; un dernier examen au centre a eu lieu à 18 ans, et des questionnaires ont été envoyés aux sujets aux environs de leur vingt et unième anniversaire.

Les abandons concernent près de la moitié de l'échantillon initial.

Pertes selon l'âge au moment de l'abandon

Age	Nombre d'abandons	% par rapport au nombre total de sujets	% par rapport au nombre de sujets restants
0 à 1 an	31	11,9	11,9
1 à 4 ans	32	12,4	14,0
5 à 9 ans	28	10,8	14,3
10 à 14 ans	24	9,3	14,3
15 à 18 ans	7	2,7	4,9
Total	122	47,1	59,4

L'évolution sociale de l'échantillon, de la naissance à 18 ans, témoigne d'une amélioration générale du niveau social au cours du temps et de la disparition totale des familles de classe V au bout d'une dizaine d'années, par abandon ou accession à une classe supérieure; ce phénomène est normal étant donné que de nombreuses familles étaient, au moment de la naissance de l'enfant, des familles jeunes, n'ayant pas encore atteint le niveau optimum dans leurs activités professionnelles, ni même dans leurs études. Nombreuses sont celles également qui ont déménagé, l'âge des enfants ou leur nombre exigeant un logement plus vaste. Cette caractéristique intervient également dans l'évaluation du niveau social global.

Evolution du niveau socio-économique des familles

Age / Classe Sociale	Naissance		3 ans		9 ans		12 ans		18 ans	
	N.A.	%	N.A.	%	N.A.	%	N.A.	%	N.A.	%
I	5	2,7	6	3,3	5	3.6	7	5,7	9	7,3
II	42	22,5	56	30,4	50	36	46	37,7	48	38,7
III	88	47	84	45,7	65	46,8	55	45,1	48	38,7
IV	46	24,6	33	17,9	18	12,9	14	11,5	19	15,3
V	6	3,2	5	2,7	1	0,7	0	0	0	0
Total	187		184		139		122		124	

Une étude concernant l'évolution individuelle des niveaux socio-économiques de 187 familles montre que 118 familles (soit 63,1 % d'entre elles) présentent une amélioration, 53 familles (soit 28,9 %) se caractérisent par une stabilité du niveau social pendant toute la période d'observation, cependant que 16 familles (soit 8,6 %) subissent une diminution de leur niveau social.

Etat actuel des données

Dans le tableau suivant, nous reprenons une brève énumération des thèmes généraux qui ont été abordés tout au long de l'enquête, dans les divers questionnaires présentés à la mère et à l'enfant et au cours des examens somatiques et psychologiques de l'enfant.

Analyse globale des données de l'échantillon

Au terme des dix-huit années d'observation, les dossiers des enfants examinés se répartissent comme suit:

Dossiers complets	74
Dossiers complets à 90 %	113
Dossiers incomplets (— de 90 %)	72
	259

Malgré le nombre relativement élevé d'abandons, le matériel permettant une analyse longitudinale était suffisamment important et original pour que cette étude soit entreprise. Dans cette optique, les dossiers incomplets ont été supprimés de l'échantillon qui se réduit à 187 sujets (99 garçons et 88 filles). Les informations disponibles, corrigées et enregistrées sur bandes magnétiques, étaient au nombre de 4044 par sujet.

Un premier passage sur ordinateur a fourni les distributions de ces nombreux paramètres.

Une sélection a été effectuée de manière à conserver ceux qui seraient susceptibles de faire l'objet d'une analyse; c'est ainsi que, dans une première étape, 573 variables ont été groupées dans un sous-fichier concernant les 187 sujets étudiés.

Une seconde étape de l'aménagement des données a consisté dans l'élaboration de données résumées, rendant compte des observations effectuées pendant une période qui s'étend sur un certain nombre d'examens successifs. Ces groupements correspondent aux périodes du développement qu'ils recouvrent. Par exemple les fréquences de colères observées à 1, 3, 6, 9, 12, 18 et 24 mois ont été combinées de manière à obtenir une valeur moyenne de la fréquence des colères observées pendant la **petite enfance**. La même opération a été appliquée aux mêmes observations relatives à la période qui s'étend de l'âge de 3 à 9 ans inclus; la note résumée obtenue concerne donc la fréquence des colères pendant l'**enfance**. Une troisième période a également été envisagée: elle débute avec la dixième année et s'étend jusqu'à la quinzième année. Elle correspond à ce que nous avons appelé la période **péri-pubertaire**.

Outre ce regroupement dans le temps, nous avons également procédé à une combinaison des diverses données correspondant à un même phénomène. Nous avons ainsi, dans certains cas, effectué une synthèse des données qualitatives et quantitatives. L'intensité et la fréquence des colères observées pendant une période a, par exemple, été combinée de manière à rendre compte d'une façon aussi objective que possible du phénomène en question.

C'est ainsi que le nombre de données retenues pour chacun des 187 cas étudiés a été finalement limité à 68 variables qui rendent compte des divers aspects du comportement de l'enfant, des attitudes parentales, des conditions de milieu familial, ainsi que d'un certain nombre de variables critères observées à l'âge de 18 ans. Il importe de noter que le nombre d'examens effectués à 18 ans est limité à 120 sujets. Les critères établis à ce niveau d'âge ne s'appliquent donc pas à l'ensemble de l'échantillon. Des études d'associations entre les premières périodes de la vie ont néanmoins pu être effectuées pour les sujets qui n'ont pas été revus à l'âge de 18 ans.

ÉTAT ACTUEL DES DONNÉES[1]

Examens et questionnaires	Mois					Années														
	1	3	6	12	18	2	3	4	5	6	7	8	9	10	11	12	13	14	15	18	21
Antécédents, grossesse, accouchement	O																				
Enquête sociale à domicile	V						V					V				V				V	
Alimentation	O	O	O	O	O	O	O														
Santé, examen clinique	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	
Mesures somatiques	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	
Age osseux	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	
Signes pubertaires														+	+	+	+	+	+		
Age des premières règles													V	V	V	V	V	V			
Photos	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	
Interview de la mère																					
Régime alimentaire	O	O	O	O	O	O	O														
Comportement enfant	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	
Vie scolaire - loisirs							V	V	V	V	V	V	V	V	V	V	V	V	V	V	
Echelle d'attitudes de la mère	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	
Questionnaire sur les habitudes éducatives (P.A.R.I.)																	V				
Interview de l'enfant																					
Vie scolaire, familiale, loisirs, projets d'avenir															V	V	V	V	V	V	
Questionnaire vie familiale, professionnelle, études																					+
Echelle d'attitude de l'enfant	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	

Examens et questionnaires	Mois					Années													
	1	3	6	12	18	2	3	4	5	6	7	8	9	10	11	12	13	14	15	18	21
Epreuve de développement psychomoteur de Brunet-Lézine	.	v	v	v	v	v															
Epreuves intellectuelles																					
Terman Merril							V		V		V		V		V						
PMA de Thurstone																		V			
D 70																				V	
Vocabulaire de Meuris																				V	
Dessins																					
Goodenough									+		+		+								
Famille															+						
Angst & Lust (beeld) («Fear and pleasure»)																	+				
Autres épreuves																					
Cube de Kohs														+							
Bouteille de A. Rey								+	+												
Fables de Düss								V		V											
Bestiaire de Zazzo									V	V											
CAT												+									
Test musical														+		+					
Van Lennep															+						

+ données brutes
O sur cartes perforées
V sur bande
n négatifs

Etudes de la croissance et du développement, Dakar
The Dakar Studies of Growth and Development

Fondateur: Prof. Jean Sénécal.

Dr G. Massé, 1954-1958.
Dr C. Bardet (psychiatre).
Mme Chabaud (infirmière).
Mme Galmiche (photos, radios).
Mme Faget-Le Cuyader (assistante sociale).
M. J. Diouf (secrétaire).
M. O. N'Diaye (chauffeur: convocations, recherche des cas après déménagements).

Mme Moreigne (psychologue), 1958-1960.
Dr P. Cantrelle.
M. J. Diouf.
M. O. N'Diaye.
Dr G. Massé: dépouillement hors Dakar.

Dr G. Massé, 1960-1962.
Mme Moreigne.
Mme Senghor (assistante sociale).
M. J. Diouf.
M. Sall (technicien du Centre de P.M.I.).

Dr G. Massé: dépouillement hors Dakar, 1962-1966.

Dr Bouthreuil (reprise de l'étude somatique et enquête sociale), 1969-1970.

Dr I. Niang, 1970-1979.
M. A. Diop et coll. (2e Enqu. sociologique). I.F.A.N. en 1972-1973.
M. J. Diouf.
M. O. N'Diaye (chauffeur).
Dr F. Touré (E.E.G.: relation avec état nutritionnel des 2 premières années).
Mme Michaux (analyse maturation osseuse). (hors Dakar.)
Dr G. Massé (dépouillement et analyse). (hors Dakar.)

ETUDES EN COURS

Matériel d'études

1. Données recueillies auprès des 191 adolescents restant de la cohorte née en 1954-56.

Après une interruption de 7 années, ces adolescents ont été retrouvés en 1969 par le Dr Bouthreuil et suivis régulièrement depuis, tous les 6 mois, par le Dr Niang à l'Institut de Pédiatrie sociale, jusqu'en 1976. Certains garçons n'ayant pas terminé leur croissance ont été réexaminés en 1978. Les filles ont été réexaminées à l'occasion de leurs grossesses.

2. Données recueillies auprès de la 2e génération: les premiers enfants sont nés en 1970; à la fin de 1978, 152 naissances au total avaient été enregistrées.

Analyse des données: objectifs

1. Analyse de la croissance

a) Etude de la fin de la croissance.

b) Etude des liaisons entre les caractéristiques de la croissance aux différentes étapes de celle-ci.

2. Analyse du développement pubertaire

a) Etude de l'apparition des différents phénomènes pubertaires.
b) Etude des liaisons entre ces phénomènes.

3. Analyse des relations entre la croissance et le développement pubertaire (et en particulier, croissance du bassin après les premières règles, étant donné l'importance numérique en milieu africain des grossesses survenant peu après, et des dystocies.

4. Comparaison de la croissance des deux générations pendant les premières années

a) En tant que groupes globaux.
b) En tant que séries appariées, parents-enfants.

ÉTUDES LONGITUDINALES — DAKAR

Enquête	Type de données	Forme des données		Support des données			Analyse	Publication
		Brutes	Nettoyées	Fiches	Cartes perforées	Bande		
1re génération								
— *0-6 ans:*	Mesures somatiques	+	+	+	+	+	+	+
	Maturation psychologique	+		+			+	+
	Maturation osseuse	+	+	+	partiellement		+	+
	Enquêtes sociales	+		+			+	+
— *Puberté*								
— *Age adulte:*	Mesures somatiques	+	+ ♀ en cours ♂	+	+	incessamment	+ ♀ en cours ♂	(rapport)
	Maturation osseuse	+	+	+	+		+	+
	Maturation pubertaire	+	+	+	+	incessamment	+ ♀ en cours ♂	(rapport)
	Enquêtes sociales	+		+	+			
	Enquête sociologique (de type transversal)	+		+	+		+	(rapport)
	E.E.G.			+			+	(rapport)
2e génération								
(0 à 8 ans pour les plus âgés)	Mesures somatiques	+	+	+	+		en cours	

ÉTUDES LONGITUDINALES — DAKAR[1]

Dates	Ages	Types de données	Support des données			Analyse	Publication
			Fiches	Cartes perforées	Bandes		
1953-54	0-18 mois	Tailles et poids, semi-longitudinales.	+			+	+
1956-57	2- 7 ans	Tailles, poids, plis cutanés, maturation osseuse, maturation dentaire.	+			+	+
1953-54	6-15 ans	Tailles, poids.	+			+	+
1954-55	7-17 ans	Maturation sexuelle.	+			+	+
1956-57	6-15 ans	Tailles, poids, plis cutanés, maturation osseuse, maturation dentaire.	+			+	+
1954 1957 1961	10-50 mois	Maturation osseuse d'enfants atteints de Kwashiorkor	+			+	+
1970	12-16 ans 1/2	Mesures somatiques id. enquête longitudinale. Maturation pubertaire et dentaire.	+	en cours		prochainement	

Etude de la croissance et du développement de l'enfant, Kampala, Ouganda

Fondateur: Dr R. F. A. Dean

Directeur: Dr M. Geber

Cette recherche a commencé en 1954, à Kampala, au Laboratoire de Recherche sur la Malnutrition Infantile du Medical Research Council, à l'Hôpital Mulago de Kampala, sur l'instigation du Dr R. F. A. Dean (décédé), Directeur de ce Laboratoire.

Le point de départ a été l'étude de la relation mère-enfant, au cours du kwashiorkor, et du comportement du petit malade dont le niveau de développement était aussi évalué. Il s'est alors avéré nécessaire d'examiner, à fin de comparaison, des enfants sains de même âge, c'est-à-dire entre 12 et 30 mois. Cette première recherche a été financée par l'O.M.S.

Les résultats obtenus ayant intéressé le C.I.E., la recherche, dès 1955, a été financée, en partie, par le C.I.E., en partie par le Medical Research Council. Elle s'est poursuivie 3 mois par an, en juillet, août et septembre. Les mêmes enfants n'ont donc pas été examinés à 3 mois, 6 mois, 12 mois, 18 mois, comme dans les autres pays, mais toujours à 1 an d'intervalle, 1 mois, 12 mois, 24 mois, 36 mois; 3 mois, 15 mois, 27 mois, 39 mois; 6 mois, 18 mois, 30 mois, 42 mois, etc.

Il apparaît d'autre part important de signaler qu'il n'existe pas d'enregistrement d'état civil des Africains en Ouganda, et que la population essentiellement répartie dans de petits villages de 20 à 30 cases, est très mouvante. Ceci nous a conduits à n'inclure dans notre recherche que des enfants nés à l'Hôpital, pour être sûrs de leur date de naissance, et dont les familles habitaient au maximum à une vingtaine de kilomètres de Kampala, les transports étant extrêmement rares. Enfin, nous avons tenté de connaître par les chefs de villages, les familles susceptibles d'être stables, afin de poursuivre notre enquête le plus longtemps possible.

Le recrutement s'est fait de 1954 à 1957 dans le but d'avoir un nombre suffisant d'enfants pour une étude longitudinale et aussi issus de milieux suffisamment diversifiés pour représenter les différentes classes sociales.

Les enfants de l'enquête longitudinale ont tous été examinés à domicile. D'autres enfants, examinés dans les dispensaires, les jardins d'enfants, ont fait l'objet d'études comparatives transversales, et ceci pas seulement en Ouganda, mais aussi au Sénégal, au Congo (actuel Zaïre), en Afrique du Sud, en Zambie.

Les enfants suivis relevaient tous d'une même tribu, les Baganda, mais avaient été recrutés dans différents milieux sociaux où l'accent a pu être mis sur le mode de vie, le plus souvent traditionnel à la campagne, et presque toujours moderne à la ville.

L'enquête longitudinale s'est progressivement enrichie des puînés. Il est en effet impensable, en Afrique, d'aller dans une famille et de ne pas s'intéresser aux bébés. En Ouganda, l'enfant de moins de 6 mois est toujours offert au visiteur en signe de bienvenue et n'est repris par la mère pendant la visite que s'il manifeste un besoin physiologique sur lequel, d'ailleurs, la mère ne se trompe jamais (alimentation, miction, défécation).

L'étude ayant amené à constater dès les premiers examens la précocité des petits Africains, 170 nouveaunés furent examinés en Ouganda et 90 en Zambie.

La recherche, par suite des événements politiques (Indépendance) et la mort du Dr Dean, a été interrompue de 1960 à 1970. Aucun enfant de l'enquête longitudinale n'a donc pu être examiné entre 6 et 16 ans. Cette enquête a été reprise en 1970, grâce à une bourse de l'O.M.S., et continuée en 1972 par un financement de l'Aquinas Fund consenti au Laboratoire de Psychologie clinique individuelle et sociale de l'Université de Paris VII.

Les 4 premières années, l'équipe comprenait le Dr R. F. A. Dean, tout particulièrement intéressé par les effets de la malnutrition sur la croissance, le Dr P. R. M. Jones assurait les différents examens anthropométriques et radiologiques, le Dr Marcelle Geber appliquait les tests de développement psychomoteur, menait l'entretien avec les mères et faisait ses visites à domicile pour l'enquête sociologique. Seules les enquêtes psychologiques et sociologiques ont été continuées, puis reprises après une interruption de 10 ans. Les données somatiques furent remises au Dr J. S. Tanner pour le dépouillement.

Les résultats des examens psychologiques et de l'enquête sociologique ont donné lieu à différents articles, a plusieurs communications, à des congrès, à un film (réalisé en 1959).

Cette étude a permis:

— de comparer le développement psychomoteur des enfants de milieu rural, élevés selon la tradition, à celui d'enfants de même tribu, habitant le plus souvent la ville et élevés de manière moderne. Les enfants de milieu traditionnel, constamment avec leur mère, portés au dos, dormant contre elle, allaités à la demande, étaient très précoces jusqu'au sevrage; pendant une année, ils faisaient peu d'acquisitions; puis, à la fin de la 3e année, ils progressaient à nouveau. Les enfants de milieu urbain et acculturé étaient moins précoces au début et poursuivaient leur développement plus régulièrement (cf. L'environnement et le développement des enfants africains, Enfance, 1973, n° 3-4, pp. 145-174).

— de montrer combien une épreuve faisant partie de la culture et valorisée par celle-ci n'influence que transitoirement le développement, aussi dramatique que puissent paraître les réactions qu'elle entraîne (séparation au moment du sevrage en Ouganda). Les mêmes enfants, apathiques en pleine période de sevrage, furent retrouvés des adolescents dynamiques et capables de se projeter dans une vie personnelle intéressante et un avenir professionnel très valable pour la communauté. Il est vrai que le sevrage, avec séparation de l'enfant de la mère pour le confier à la femme la plus âgée de la famille, est une sorte de rite d'initiation — le seul existant pour les Baganda — et qui permet de passer de l'état de nourrisson à celui d'enfant déjà responsable de lui-même.

— de souligner l'importance de l'environnement non seulement sur le développement de l'enfant, tant affectif qu'intellectuel, mais aussi sur la gestation et le nouveau-né (cf. Le développement des nouveau-nés africains, Courrier, Vol. XXVII, 1977, n° 6, et Revue Internationale de Pédiatrie, 1978, n° 81).

— de mettre en évidence que l'éclosion d'une maladie telle que le kwashiorkor n'est pas due seulement à la malnutrition, mais aussi au contexte psychologique (cf. Psychological factors in the etiology of kwashiorkor, Bull. O.M.S., 1955, n° 12, pp. 471-475). Parmi les 25 enfants atteints de kwashiorkor et examinés en 1954, 5 seulement furent retrouvés en 1970, les familles ayant plusieurs fois déménagé. Contrairement aux familles de l'enquête longitudinale, les 5 familles avaient un niveau socio-économique qui se dégradait et les 5 foyers étaient dissociés.

— de constater qu'à une amélioration du niveau socio-économique se surajoutait souvent une angoisse, une inquiétude de l'avenir. Les progrès étaient particulièrement notables pour l'habitat: les habitations étaient en dur et non plus faites de boue et de roseaux; une citerne recueillait l'eau de pluie et la filtrait. Deux familles seulement allaient chercher l'eau au marigot. Les conditions d'hygiène étaient certes meilleures. Par contre, surgissaient des difficultés sur le plan psychologique, surtout en milieu rural. Pour gagner l'argent nécessaire à la vie familiale, à la scolarité, les pères allaient bien souvent travailler en ville et ne revenaient qu'une fois par mois alors que les mères restaient au village avec les plus jeunes. Les aînés, par leur savoir scolaire, leur fréquentation de la ville, devenaient pour les mères des inconnus.

La femme, au rôle si important en milieu rural, était dévalorisée. Elle n'était plus l'épouse avec qui le mari décidait, ni la mère à laquelle les enfants se référaient et à qui ils témoignaient leur respect. Les filles répugnaient au long travail qu'est la préparation de la cuisine.

Il est à remarquer qu'au début de notre étude, en 1954, ce sont les mères de familles qui avaient adopté un genre de vie à l'occidentale qui paraissaient les plus angoissées, tiraillées entre la vie moderne vers laquelle les maris les entraînaient et la vie traditionnelle que leur propre mère les incitait à respecter.

Les coutumes changent extrêmement rapidement en Afrique. En milieu traditionnel, le sevrage était vers 20 mois en 1954, vers 8, 10 mois en 1960; le bébé dormait sur la même couche que la mère, peau contre peau; en 1970 il avait un berceau. Il serait intéressant d'étudier si, à la longue, ces modifications ne sont pas sans changer le rythme de développement des enfants.

La rupture avec la tradition amène un profond malaise: la crainte de mécontenter les mânes des ancêtres, toujours présents à chaque foyer, et l'insécurité de l'avenir dans un nouveau monde mal assimilé.

L'école tend plus à accentuer les différences entre les enfants des familles pauvres, analphabètes, démunies, et ceux des familles intellectuelles et pourvues, qu'à les combler.

Les enfants du milieu traditionnel n'étaient scolarisés que vers 6, 7 ans ou même plus tard. Ils vivaient dans des cases sans électricité, n'avaient pas de livres à leur disposition et n'entendaient parler l'anglais que sur les transistors. Parmi les 28 adolescents qui ont pu être revus en 1970 et 1972, 4 seulement avaient accédé au secondaire.

Les enfants de milieu socio-économique supérieur (pères universitaires, hauts fonctionnaires) allaient au jardin d'enfants, habitaient des maisons bien équipées en matériel divers, avaient des livres à leur disposition, entendaient parler anglais. Les 30 adolescents revus en 1970 et 1972 étaient tous en secondaire.

Il est à noter que les écoles secondaires sont très coûteuses et donc difficilement accessibles à la classe pauvre.

Une telle recherche s'étalant sur de si nombreuses années devrait pouvoir mieux dissocier les différents facteurs qui influencent le développement de l'enfant. Elle devrait pouvoir permettre une certaine prévention.

Un travail s'étalant sur presque 20 années en Afrique fait poser cette question: comment faire pour qu'une amélioration physique (diminution de la morbidité, de la mortalité) et sociale (meilleure hygiène, maisons plus confortables) s'accompagne d'un mieux-être mental, non seulement intellectuel, mais aussi affectif?

Il est dommage que dans l'étude longitudinale des différents pays d'Europe, il n'a pas été possible de comparer des enfants élevés par la mère, et d'autres en crèche.

Les comparaisons entre des modes de maternage, d'élevage, d'éducation différents permettraient sûrement de mieux connaître ce qui est le plus bénéfique pour que croissance physique et développement psychologique se fassent le plus harmonieusement et le plus complètement possible en permettant ensuite aux individus d'utiliser pleinement toutes leurs capacités tant physiques que psychiques.

London Longitudinal Growth Study

1. The Longitudinal Study of Psychological Development, 1949-1980

Team Members:

Founder: Miss D. E. M. Gardner
Director: Prof. C. B. Hindley

Psychologists:

Prof. T. W. Moore, 1949-1966
Prof. C. B. Hindley, 1949-
Miss J. A. Munro, 1967-1972
Mr. A. Salmon, 1967-1970 (part-time)
Mr. B. Medjuck, 1973-1975
Mr. C. F. Owen, 1973-1976
Dr. B. M. Giuganino, 1974-

Honorary Research Associates:

Mrs. L. Ucko, 1951-1967
Prof. T. W. Moore, 1967-

Secretary:

Mrs. S. E. Clautour, 1961-

Among those who have helped for shorter periods, or intermittently, have been:

Staff of Institute of Education:

Prof. D. Lee
Dr. M. Marshak
Dr. A. H. Bowley
Miss J. Cass
Dr. B. Baughan

Research Assistants:

Mrs. I. Lewis
Miss L. Dorling
Mrs. D. Leikowitz
Mr. C. Cooper
Mrs. C. Batarda-Fernandez
Mrs. R. Freeman
Miss S. Sharpe
Mr. A. Sutherland
Miss P. Howie

Secretaries:

Mrs. D. Gardner
Miss S. Wisdom
Miss C. Tibbetts
Miss A. March
Mrs. I. Gardner
Mrs. J. Walker
Mrs. U. Atkins
Miss S. Balkind
Mrs. L. Clark

Financial support:

From 1949 to date: University of London Institute of Education
1970 to 1975: Social Science Research Council
1974: The Vanessa Lowndes Charitable Trust
1974 to 1978: Leverhulme Trust

PRESENT STATUS OF THE DATA

Numbers in sample

Age	N	Percent of Total
Birth	222	
18 months	185	83.3
5 years	171	77.0
10 years	141	63.5
15 years	120	54.1
16 years	109	49.1
17 years	102	46.0
18 years	70	31.5

Social Class at Birth:

	1	2	3	4	5	No. information
Graffar Classification	2	29	64	120	5	2
Father's Occupation	8	34	131	26	21	2

Data available

The forms, questionnaires, and tests used at each age, along with a more detailed list of tests administered to the research subjects are appended. The data exist in various stages of elaboration. Most of the data from 4 years are at least codified in a form from which they can be punched. Many aspects, and in particular those on which extensive analysis has been carried out, are punched on cards.

(Detailed lists of data are kept at the Centre for the Study of Human Development.)

Forms used — By age

Up to 3 months

M1 Recruitment Interview
M2 Ante-Natal Interview
M3 Lying-In Interview
M35 Infant's Night Sleep (Home Confinement) (Sleep Enquiry - D Group Volunteers only)
M36 Infant's Night Sleep (In Hospital) (Sleep Enquiry - D Group Volunteers only)
M4 Lying-In Period (Hospital Report)
M5 Midwife's Report on Mother
M6a Hospital Medical Form
M6c Mother's History at 4 weeks
M11 Case Summary
M12 Home
M37 3 week Interview (Sleep Enquiry) - D Group Volunteers only
M13 (3rd rev.) 6 week Interview
M14 (Rev.) Observations during Medicals
M38 9 week Interview (Sleep Enquiry) - D Group Volunteers only
M50 Home Ratings for Visitors
M58 Social Data at Birth
M40 Five Month Interview (Sleep Enquiry) - D Group Volunteers only
M41 Eight Month Interview (Sleep Enquiry) - D Group Volunteers only

By the mother	By the child
3 Months	
M15 (Rev 3) 3 Month Interview	**M16** Social Behaviour Test No. 1 (Groups A & B) **M21** Ratings at 3 Months Griffiths Test (Groups C & D)
6 Months	
M7 Social Behaviour — M.'s Report **M20** (Rev 3) 6 Month Interview * M19 Check List on Mother	**M21** Ratings on Griffiths Test Griffiths Test
9 Months	
M22 (3rd Rev) 9 Month Interview **M26** Day Sampling 6-9 Months	**M21** Ratings on Social Behaviour Test **M23** (Rev) Social Behaviour Test No. 2
12 Months	
M24 (3rd Rev) 12 Month Interview	**M21** Ratings at 12 Months **M25** Social Behaviour Test No. 3 (Groups A, B, C) Griffiths Test (Group D)

By the mother	By the child
18 Months	
M28 (Rev 3) 18 Month Interview	**M32** Ratings on Griffiths Griffiths Test (All Groups)
2 Years	
M33 (Rev 3) Two Year Interview	**M34** Picture Vocabulary **M34** Free Play Description **M34** Ratings at 2 years
2½ Years (Home Visit)	
M39 Two and a half year Home Visit **M49a** Speech Enquiries at 2½ years **M49d** Visitors' Observations at 2½ years **M49e** Speech Stimuli at 2½ years	**M49** Speech Observed
3 Years	
M42 Ratings for Interview with Mother at 3 years **M43** (Rev 1) Three year Interview	**M34** Ratings at 3 years (A group only) **M46a-d** Ratings at 3 years B, C and D groups **M46e** Additional Ratings at 3 years (D group only) Stanford Binet Form L Merrill Palmer Puzzles 1-3 (Pre-Test) Goodenough Draw a Man
4 Years	
M42 (1st Rev) Ratings for Interview with Mother **M46a-x** 4 Year Interview with Mother **M47** 4 Year Supplementary Social Data **M48** Observations during Medical Examinations (4 years onwards)	**M51** Report on Child at 4 years Goodenough Draw a Man Performance Tests World Test Draw-a-House Draw-a-Family Doll Play (M51 d-k) Ratings
5 Years	
M52 (CO) Interview with Mother	**M53** Report on Child at 5 Years Buhler World Test (Plan and Description of Themes) Pavlov Typing Ratings and Handedness Bestiaire Lerner Blocking Test Binet (Form L)

By the mother	By the child
6 Years	
M55 (CO) Home Enquiry **M56** (CO) Mother's Report at Centre **M57** (CO) Shortened Interview with Mothers	Doll Play Technique and Ratings
7 Years	
M55 (Rev 1) Home Enquiry **M56** (Rev 1) Mother's Report at Centre **M57** (Rev 1) Shortened Interview with Mother	**M64** Report on Child at 7 Years Schonell Graded Reading Vocabulary Test (RI) Bestiaire Lerner Blocking Test Touch and Smell Reactions Ratings Pavlov Typing
8 Years	
M55 (Rev 1) Home Enquiry **M57** (Rev 1) Shortened Interview with Mother **M66** Mother's Views about Children & Family Life (PARI)	**M65** Report on Child at 8 Years Binet Form L Rosenzweig P-F Test Erickson Play Situation Ratings
9 Years	
M55 (Rev 1) Home Enquiry **M56** (Rev 1) Mother's Report at Centre **M57** (Rev 1) Shortened Interview with Mother	**M68** Report on Child at 9 Years Ratings World Play Diagrams and Themes
10 Years	
M55 (Rev 1) Home Enquiry **M57** (Rev 1) Shortened Interview with Mother **M70** Mother's Form 10 years (MPI, Interests, Mill Hill Vocabulary Test)	**M69** (CO) Questionnaire on Children's Activities (completed by Mother and Child) **M71** Report on Child at 10 Years Junior MPI Jung List Personality Typology Rosenzweig Picture Frustration Test
11 Years	
M55 (Rev 1) Home Enquiry **M56** (Rev 1) Mother's Report at Centre **M57** (Rev 1) Shortened Interview with Mothers **M72** Interviewer's Comparison of old and new questions on M56 at 11 Years	**M73** Report on Child at 11 Years CBH's Touch, Smell, Sucking Pleasure Reactions Collecting Pavlov Typing Ratings Binet Form L-M
* M59-M62 School Enquiry Forms (used at 11-12 years APX)	

By the mother	By the child

12 Years

M55 (Rev 2) Home Enquiry
M57 (Rev 2) Shortened Interview with Mother
M75 Mother's Forms at 12 Years
Oppenheim: Parent Attitude Inventory
Parent Behaviour Inventory

M74 Interview with Subject at 12 Years
(old version) A Group only
Rorschach (timed)
Sucking Pleasure
Ratings
* New Version: Quest. 16 changed and

13 Years

M55 (Rev 2) Home Enquiry
M57 (Rev 2) Shortened Interview with Mother
M76 (Revised M56) Mother's Report on Adolescent

M69 (Rev 1) Questionnaire on Children's Activities (completed by Child and Mother together)
M77a-p Subject form at 13 years
School subject cards -ranked
Favourite activities -ranked
Osgood —feelings about words
(Semantic Differential)
M77 1.-6. Factorial Interest Form at 13 Years
(Instruction Form) NB—Answer Sheet M77p
M78 Interview with Subject at 13 Years
Pavlov Typing and Ratings

14 Years

M55 (Rev 2) Home Enquiry
M57 (Rev 2) Shortened Interview with Mother
M76 (Revised M56) Mother's Report on Adolescent

M77a-e Subject's Form at 14 Years
Favourite Activities, Ranked
School Subject Cards, Ranked
M79 Interview with Subject at 14 Years
Ratings
AH4

15 Years

M55 (Rev 3) Home Enquiry
M57 (Rev 2 & pg p-v) Shortened Interview with Mother
M76 (Revised M56) Mother's Report on Adolescent
M83 Mother's Form at 15 Years
(Semantic Differential)

M69 (Rev 2) Questionnaire on Teenager's Activities
M80 (CO) Teenager's Interests
M81 Subject's Form — 15 Years
Junior HSPQ
Semantic Differential (Feelings about Words)
Ideas
Feelings about Things (Worries)
* Uses
M82 Interview with Subject — 15 Years
Ratings
Pavlov Typing
M84 School Visit at 15 Years

* M86 Behaviour Questionnaire (compl. by schools at 15 Years)

By the mother	By the child
16 Years	
M55 (Rev 4) Home Enquiry **M57** (Rev 3) Shortened Interview with Mother **M76** (Revised M56) Mother's Report on Adolescent	**M80** (Rev 1) Teenager's Interests Questionnaire **M85** School and Work Questionnaire **M87** Interview with Subject at 16 Years Ratings/Pavlov Types **M88** Test Form at 16 Years 'What Matters' (values) * TAT (recorded) Card Sorting
17 Years	
M55 (Rev 4) Home Enquiry	**M80** (Rev 2) Teenagers' Interests **M85** (Rev 1) School & Work Questionnaire **M89** Subject's Form at 17 Years Uses of Things Eysenk Radicalism vs. Conservatism; Tough-Minded vs. Tender-Minded (Opinions R & T) Abbreviated M.P.I. Meanings of Things Baron Welsh A.H.4. **M90** Investigator's Form at 17 Years
18 Years	
M55 (Rev 4) Home Enquiry	**M80** (Rev 2) Teenagers' Interests **M85** (Rev 2) School & Work Questionnaire IPAT 16 PF Form E

PSYCHOLOGICAL TESTS GIVEN TO SUBJECTS

Age	Description of tests
8 Days	Sleep Enquiry (Infant's Night Sleep Home Confinement Hospital)
4 Weeks	Medical Session only, No Psychological Session
6 Weeks	NIL
3 Months	Griffiths (C & D Groups only) Social Behaviour Test 1 (A & B Groups only)
5 Months	Sleep Enquiry (M40) D Group only
6 Months	Griffiths (All Groups)
8 Months	Sleep Enquiry (M41) D Group only
9 Months	Social Behaviour Test 2
12 Months	Griffiths (D Group only) Social Behaviour Test 3 (A, B, C Groups only)
18 Months	Griffiths (Total Sample)
2 Years	Speech Test (Picture Vocabulary) Free Play (Description)
2½ Years (Home Visit)	NIL
3 Years	Form L—Binet Merrill-Palmer Puzzles 1-3 (PRE TEST) Goodenough Draw a Man
3½ Years (Home)	NIL

Age	Description of tests
4 Years	World Play Situations (World Test) M51n Doll Play Techniques Performance Tests Goodenough Draw a Man Test
5 Years	Binet Form L Bestiaire Lerner Blocking Test World Play Situations Bühler World Test (Plan & Description of Themes) Pavlov Typing
6 Years	Doll Play Techniques (M51d-k) + Ratings
7 Years	Schonell Graded Reading Vocabulary Test (RI) Bestiaire
M64	Lerner Blocking Test Touch and Smell Reactions Pavlov Typing
8 Years	Form L—Binet Rosenzweig Picture Frustration Erickson Play Situations
	Mother (8 Years)
	Schafer & Bell (Pari)—Mothers' Views About Children and Family Life
9 Years	World Play Diagrams/Themes
10 Years	Activities Questionnaire (Mother and Child together) Junior MPI Jung List Personality Typology Rosenzweig Picture Frustration
	Mother (10 Years)
	MPI Interest Vocabulary
11 Years	Binet Form L-M CBH's Smell and Touch Reactions Sucking Pleasure Pavlov Typing Collecting
12 Years	Roschach CBH's Pleasure in Sucking Test

Age	Description of tests
M74	**Mother** (12 Years) M75 Openheim's Parent Attitude Inventory Parent Behaviour Inventory
13 Years	Factorial Interest Form
M77 1-6	Semantic Differential (Osgood) - Feelings about Words
M77 a-p	School Subject Cards—Ranked
M78	Favourite Activities—Ranked Pavlov Typing Questionnaire on Children's Activities (completed by Mother & Child)
14 Years	AH4 School Subject Cards—Ranked Favourite Activities—Ranked
15 Years	Junior HSPQ (timed)
M80	Teenagers' Activities Questionnaire "Feelings" about Words (Semantic Differential) Pavlov Typing Teenagers' Interests "Ideas" (uses) Feelings about Things (Worries Questionnaire)
	Mother (15 Years)
	MPI Semantic Differential
16 Years	TAT (recorded)— Thermatic Apperception Test Teenagers' Interests Questionnaire Pavlov Typing Card Sorting—What Matters To You (Values)
17 Years	AH4 (timed) Teenagers' Interests Questionnaire Baron Welsh "Uses" of Things Form "Meanings" of Things Form Opinions (Eysenck: Radicalism vs. Conservatism; Toughminded vs. Tenderminded) MPI (Abbreviated)
18 Years	IPAT—16 PF (Form E) Teenagers' Interests

2. The London Longitudinal Somatic Study

Founder: Professor F. Falkner
Head: Professor J. M. Tanner

Physician

Professor F. Falkner, 1951/55
Present Professor J. M. Tanner, 1956
Dr. W. Israelsohn, 1960/62
Professor W. A. Marshall, 1964/75
Present Dr. M. A. Preece, 1974

Mathematician

Professor H. Goldstein, 1964/75

LOSSES FROM LONDON SAMPLE

Boys

Age period	Loss during period	Percent of number at age 1	Percent of number at beginning of period
1- 5	7	8.14	
5-10	7	8.14	8.86
10-15	10	11.63	13.89
15-20	32	37.21	51.61

Girls

Age period	Loss during period	Percent of number at age 1	Percent of number at beginning of period
1- 5	5	6.25	
5-10	15	18.75	20.00
10-15	23	28.75	38.33
15-20	16	20.00	37.21

Number of children seen at each age in London sample

Age	1	2	3	4	5	6	7	8	9	10	
Boys	86	79	77	79	79	78	77	77	67	72	
Girls	80	76	70	73	75	73	69	69	62	60	
Age	11	12	13	14	15	16	17	18	19	20	21
Boys	69	67	64	64	62	54	53	36	34	30	—
Girls	62	60	57	54	43	39	39	22	22	27	1

Each age group extends for six months on either side of the birthday, e.g. age 3 = 2.5 — 3.49 years.
The children were recruited between November, 1951 — April, 1954.

PRESENT STATUS OF THE LONDON DATA

Examinations and questionnaires	Age (years)																						
Contents	1/12	6/12	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
A. Family History-Pregnancy-Birth	v																						
Dates of Consultation	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
B. Health-Feeding-Medical Examination	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
C. Somatic Measurements	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	
Bone Age (Radiograph of Wrist)				v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
Signs of Puberty											v	v	v	v	v	v	v	v	v	v	v	v	v
Somatic Measurements of Parents															v								
D. Anthropometric Photographs						p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p

vvv = On Tape
ppp = Photos

L'Etude longitudinale de la croissance et du développement de Paris

Membres de l'équipe

Fondateur: Prof. Robert Debré
Directeur: Dr Nathalie P. Masse

Médecins

Dr M.-P. Roy, 1953-1959 et depuis 1968
Dr Michel Sempé, 1959

Une douzaine de médecins ont été vacataires pendant une ou plusieurs années et huit boursiers étrangers ont également collaboré à l'étude pendant leur séjour à Paris.

Psychologues

Mme A.-M. Filliozat, 1958-1967
Mme C. Thouvenin, 1959-1962
Mlle A. Salamon, 1966-1968

Assistantes sociales

Mlle J. Gaillot, 1953-1958
Mme M.-Th. Briand, 1959-1970

Statisticiens

M. J. Lellouch, 1961
Mme Tran, 1963-1969
Mlle E. Patois, 1969

Assistant technique et dessinateur

M. G. Pedron, 1961-1976

Deux caractéristiques essentielles font l'originalité de ces études:

— la méthode longitudinale qui nécessite une persévérance exceptionnelle, aussi bien des chercheurs que des sujets examinés. C'est grâce à l'intérêt passionné de Nathalie Masse pour cette enquête, à son aide constante et à celle du C.I.E., que ce travail de 22 années a pu se réaliser;

— l'enquête a été, d'emblée, pluridisciplinaire, comportant, d'une part, une étude somatique, des mesures biométriques et une radiographie de la main et, d'autre part, une étude psychologique et socio-économique. Cependant, seuls l'examen somatique et les mesures biométriques ont été effectués tout au long de l'étude; les enquêtes psychologique et sociale ont été arrêtées après 14 ans.

L'équipe de recherche a donc toujours comporté au minimum un ou plusieurs médecins, une psychologue et une assistante sociale. Prise en main avec efficacité, en 1959, par le Dr Michel Sempé, l'équipe s'est enrichie en 1961 de deux collaborations particulièrement fructueuses: celle de M. Lellouch, qui a assuré la réalisation du fichier mécanographique, et celle de M. Pédron, assistant technique et dessinateur, qui s'est consacré tout entier à ce travail.

Recrutement de l'échantillon

Pour que l'échantillon soit représentatif de tous les mois de l'année, le recrutement s'est échelonné sur quatre périodes trimestrielles, de mars 1953 à mars 1956; il a été effectué dans les 5 maternités de l'Assistance Publique proches de l'Ecole de Puériculture où ont eu lieu tous les examens au cours des 6 premières années.

439 enfants, répondant aux critères déterminés, ont été ainsi recrutés, auxquels se sont ajoutés, jusqu'en 1960, 58 frères et sœurs puinés.

L'échantillon initial global comportait donc 497 enfants: 260 garçons et 237 filles.

Evolution de l'échantillon

L'échantillon s'est réduit de moitié en 7 ans, et les changements de domicile sont sans doute les grands responsables de ces nombreuses défections.

Au moment de l'adolescence, il a été très difficile d'obtenir l'assiduité aux examens: cependant, une centaine de sujets ont pu être suivis jusqu'à l'âge de 16 et 17 ans.

Ajoutons que de Juin 1977 à Décembre 1978, il a été entrepris un long travail de recherche de l'ensemble des sujets de l'échantillon venus au moins jusqu'à l'âge de 2 ans, ceci pour connaître les caractéristiques des adultes de ce groupe: 76 sujets ont été revus à Paris et en banlieue, 25 autres au cours d'un véritable tour de France. S'y ajoutent les 33 sujets suivis chaque année jusqu'à la fin de leur croissance, ce qui porte à 134 l'effectif total dont nous connaissons les caractéristiques adultes (soit 27 % de l'échantillon initial après 25 ans). Ces ultimes données constituent une base essentielle pour valider les études prédictives de biométrie.

Fréquence et modalité des examens

Les âges auxquels les examens ont été pratiqués et leurs modalités respectent exactement les consignes de la base commune.

Les tableaux qui figurent dans le rapport de la réunion de Rennes (1976) récapitulent l'ensemble des examens faits à chaque âge dans les trois domaines, somatique, psychologique et social, et indiquent sous quelle forme se présentent les données.

Ce que peuvent faire nos études

— Mesures biométriques

C'est le domaine par excellence où l'exploitation est la plus sûre et la plus rapide.

Le but initial de l'enquête n'était en aucun cas d'établir des normes, puisque l'échantillon n'était nullement représentatif de la population parisienne, et à fortiori de la population française. C'est l'analyse dynamique des vitesses de croissance qui confère aux études longitudinales toute leur valeur.

Mais, en l'absence de larges enquêtes récentes, les données élémentaires de la croissance staturo-pondérale sont, en fait, devenues un outil national de référence en pédiatrie.

Les résultats de l'exploitation statistique de l'ensemble des mesures âge par âge et de tous les accroissements vont paraître dans un livre, actuellement sous presse, publié par M. Sempé.

Restent encore à étudier toutes les corrélations possibles d'âge en âge, ce qui est le privilège exclusif des enquêtes longitudinales et conduit à envisager le problème des prédictions. Celle de la taille est l'objet d'un travail en cours.

— Examens cliniques

Seules ont pu être exploitées l'apparition et l'évolution des caractères sexuels secondaires. Les examens cliniques sont trop superficiels dans l'ensemble pour apporter des indications valables : il est dommage, par exemple, que la mesure de la tension artérielle n'ait pas été inscrite dans les examens de routine.

L'étude de la morbidité semble difficile à réaliser à partir du questionnaire, et le bilan des accidents n'a pas été fait.

— Maturation osseuse de la main

Cette enquête est à l'origine d'une méthode très précise d'évaluation de la maturation osseuse. Le Dr Michel Sempé vient de publier un atlas récapitulant méthodologie et résultats de cette technique (référence).

— Données psychologiques

C'est un domaine dans lequel les documents accumulés sont très nombreux, mais inexploités, et ne pourront jamais l'être, ce qui est regrettable. Mais une exploitation rétrospective n'aurait plus guère qu'un intérêt historique, compte tenu des modifications si rapides de l'environnement social dans lequel vivent les enfants. D'ailleurs, les méthodes psychométriques ont fait de tels progrès depuis la date du recueil de ces données qu'une exploitation actuelle, basée sur des tests incomplets et obsolescents, comporterait beaucoup de risques d'erreurs et serait, en tout état de cause, incomplète et quelque peu anachronique.

— Données socio-économiques

Seule a été prise en compte la note sociologique globale attribuée en fonction des critères définis par M. Graffar. Retranscrite en tête de toutes les mesures somatiques, cette note permet de répartir les enfants de l'échantillon dans cinq catégories sociales.

Ce que ne peuvent pas faire nos études

— Conserver la représentativité de l'échantillon initial

Dans toute étude longitudinale, au fil des ans, non seulement l'échantillon se réduit, mais il se transforme : une sélection inévitable s'opère en faveur des catégories socio-économiques les plus élevées, ce qui introduit un biais difficile à évaluer, mais dont il faut tenir compte dans les résultats.

— Rendre compte de l'action précise de certains facteurs sur la croissance

En effet, ces études ont cherché à être aussi globales que possible, et le nombre considérable de paramètres enregistrés rend très difficile la manipulation du fichier actuel. Et, surtout, les données ont été recueillies, non pas en fonction de questions précises à résoudre, mais avec le seul souci d'effectuer une enquête aussi complète que possible.

Il s'avère donc que la sélection des renseignements recueillis n'a pas toujours été suffisante : ainsi, l'influence de la nutrition sur la croissance ne peut être abordée parce que l'enquête alimentaire est trop superficielle, et l'étude de la composition corporelle avec évaluation de la masse grasse à partir des 4 plis cutanés trop grossière, pour en tirer des conclusions valables.

Pour d'autres raisons, l'influence du milieu social ne peut pas être prouvée de façon irréfutable : en effet, déjà restreint au départ, le nombre de sujets devient très limité dans chacune des catégories sociales et ne permet plus de comparaisons statistiquement valables entre les divers groupes, et d'un pays à l'autre.

Comment notre long travail coordonné a-t-il modelé nos idées ?

Ces études au long cours coordonnées sur le plan international sont un des meilleurs exemples de coopération sans ombre, le travail persévérant de chacun étant un stimulant pour tous.

Tout en restant fidèle à la méthode consignée par

F. Falkner dans la base commune, chaque équipe a apporté au fil des ans son expérience originale et spécifique. Les modifications entraînées par l'entrée de la statistique et de l'informatique dans le domaine médical font que la méthodologie d'aujourd'hui se doit d'être différente.

Il est très probable aussi qu'une étude de si longue durée ne sera jamais répétée, et que ne seront préconisées dorénavant que des études séquentielles courtes. C'est dire toute la valeur représentée par cette description complète et pluridisciplinaire de toutes les phases de la croissance, et en particulier par l'ensemble des mesures biométriques et des radiographies qui constituent une «collection» unique et irremplaçable.

COMPOSITION ET ÉVOLUTION DE L'ÉCHANTILLON DE PARIS

Effectif examiné aux différents âges :

Age	N	1	2	3	4	5	6	7	8	9	10
Garçons	260	180	132	119	111	111	103	96	92	91	73
Filles	237	163	127	108	116	98	96	99	78	70	68
Total	497	343	259	227	227	209	199	195	170	161	141
Age	11	12	13	14	15	16	17	18	19	20	Adultes
Garçons	83	85	81	70	57	52	32	25	19	10	53
Filles	83	78	71	63	50	44	35	18	14	8	48
Total	166	163	152	133	107	96	67	43	33	18	101

Les adultes sont les sujets revus en 1977 et 1978, c'est-à-dire entre 22 et 25 ans.

Pertes

Age	Nombre	Pourcentage de l'échantillon initial restant
0- 1	91	81,7
1- 5	130	55,5
5-10	73	40,8
10-15	64	27,9
15-18	71	13,7

Nous possédons les mesures de 134 sujets adultes, soit 27 % de l'échantillon initial.

ÉTAT ACTUEL DES DONNÉES

I. Données somatiques		Age (années)																								
Examens et questionnaires	Nr.	1/12	6/12	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Adulte
A. Antécédents familiaux		+																								
Données obstétricales et périnatales (liste des données, annexe II, page 1 du rapport joint)	1	V																								
B. Etat de santé - Alimentation - Examen clinique		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	X	X	X	X	X	X	X	X	X	
C. Mesures somatiques et dentition	5	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	X	X	X	X	X
Age osseux (radio du poignet et de la main (liste des données Acheson-Greulich et TW.I, annexe II, pages 6 et 7)	6et7	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V						L'examen adulte n'a pas comporté toutes les mesures
Signes pubertaires	8											+	+	+	+	+	X	X	X	X	X	X	X	X	X	
Résumé de l'évolution pubertaire (liste annexe II, page 8)																					V					
Taille et poids des parents		V																								
Pas de photos anthropométriques																										

+ + + + + = Forme originale non codée
XXXXX = Forme originale codée
OOOOO = Carte perforée
VVVVV = Bande

ÉTAT ACTUEL DES DONNÉES[2]

II. Données psychologiques

Interviews avec la mère		Age																
A. 4 semaines à 5 ans	Nr.	1/12	6/12	1	16/12	2	26/12	3	4	5	6	7	8	9	10	11	12	13	14
Frayeur - Séparation - Milieu familial - Alimentation - Sommeil - Ecole	5	O	O	O	O	O	O	O	O	O									
Elimination et propreté - Habitudes - Peurs - Colères - Pleurs - Langage	6	O	O	O	O	O	O	O	O	O									
Activités et comportement affectif (ces formulaires ont été adoptés en 1955. Les premières interviews sont codées dans leur forme originale)	7	O	O	O	O	O	O	O	O	O									
B. 6-10 ans																			
Alimentation - Sommeil - Propreté - Langage - Comportement - Peurs	M56										O	O	O	X	X				
Frayeurs - Séparation - Milieu familial - Ecole	M57										O	O	O	X	X				
Sports - Jeux - Clubs - Organisation jeunesse (n'a pas été fait sur tout l'échantillon)													X						
C. 11-13 ou 14 ans (arrêt des examens en 1968). (Il y a aussi des interviews libres non codées à 11 et 12 ans.)																			
Frayeurs - Séparation - Milieu familial - Ecole - Camarades - Argent de poche																X	X	X	X
Modes de comportement																X	X	X	X
Activités des adolescents (questionnaire à remplir avec enfant aussi)																		X	

ÉTAT ACTUEL DES DONNÉES[1]

Tests	Age																	
	1/12	3/12	6/12	9/12	1	16/12	2	3	4	5	6	7	8	9	10	11	12	13	14
Brunet Lézine	O	O	O	O	O	O	V												
Terman-Merril (formule L)								V		V			V			V			
Dolly play									X		X								
Dessin du bonhomme									+		+								
Kohs (W.I.S.C.) (Wechsler)												+							
Labyrinthes de Porteus												+							
Bestiaire (Zazzo)												+							
Dessin d'une famille														+					
Dessin d'un arbre														+					
Thematic Apperception Test (T.A.T.)														+					
Epreuve de Rosenzweig															+				
Alexander															+				
Figure complexe Rey															+				
Ishihara															+				
Rorschach																	+		
H.S.P.Q.																		+	
A.H.4																			+

ÉTAT ACTUEL DES DONNÉES

		Age														
Interviews avec l'enfant	Nr.	1/12	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Adulte
A. 12 ans	M74																
Souvenirs - Hospitalisation - Séparation																	
Ecole																	
Avenir														X			
B. 13 ans														X			
Ecole - Activités quotidiennes - Relations	M78													X			
Estimations tirées de l'interview															X		
III. Données sociales et scolaires															X		
Liste des données (annexe II, page 3)		V		V		V		V	V		V	V	X			X	
													pour une partie de l'échantillon				
Enquête scolaire										+							
Niveau d'études et profession																	V pour une partie de l'échantillon

The Stockholm-Göteborg Growth Study

Members of the Team

Founder: Prof. Arvid Wallgren
Head: Prof. Petter Karlberg, University of Göteborg

Physicians

Dr. H. Lichtenstein, 1955
Dr. G. Klackenberg, 1955
Dr. I. Engström, University of Göteborg, 1965
Dr. J. Taranger, 1969

Psychologists

Mrs. I. Klackenberg-Larsson, 1955
Mrs. B. Olofgörs, 1958-59
Mrs. K. Widström, 1959-60
Mr. J. Stensson, 1960-67
Prof. I. Johannesson, University of Lund, 1963-79
Mrs. B. Hellbom, 1963-64
Mrs. M. Brink, 1964-65
Miss T. Poromaa, 1965-69
Mrs. Bergsten-Brucefors, University of Lund, 1966-76
Mrs. U. Lindevall, 1967-70
Mrs. E. Chamberlin, 1969-70
Mrs. L. Ricklander, 1970-71
Mrs. M. Andersson, 1971-72
Mrs. K. Björkman, 1972-78

Senior Programmers

Mr. T. Landström, University of Lund, 1970-76
Mr. B. Lindström, University of Lund, 1971-77

Statistician

Mr. J. Karlberg, University of Göteborg, 1973

Secretaries

Mrs. I. Svennberg-Redegren, 1955
Mrs. E. Tunell, 1966

Number of children in the Stockholm-Göteborg longitudinal growth study and percent of originally recruited remaining at different ages

Age	Boys		Girls		Total	
	n	%	n	%	n	%
0	122		90		212	
1	122	100	89	98.9	211	99.5
5	118	96.7	83	92.2	201	94.5
10	112	91.8	80	88.9	192	90.6
15	104	85.3	75	83.3	179	84.4
18	100	82.0	73	81.1	173	81.6
21	84	68.9	66	73.3	150	70.8

The Swedish sample consists of children from a suburban Stockholm area recruited between the years 1955 and 1958 with a distribution within social groups congruent with the one prevalent at that time for greater Stockholm school children.

All examinations of the children have been performed at the Clinic for Growth and Development of the Pediatric Department of Karolinska Sjukhuset, according to base line up to the age of 18 with addition of lung volumes from age 11 and of sociometric and different ability-tests in secondary school ages.

Between age 20 and 22 renewed contact was taken with the sample and body measurements and lung volumes were measured and a short interview on education, socioeconomic situation and health based on a questionnaire was performed. Further renewed contact with the sample around age 25 is planned.

The original number of children recruited was 212, 122 boys and 90 girls. The losses during the years have been small. At the age of 10 years, 91% of the children remained in the study and at the age 18.82% remained. At the age of 20-22, it was possible to recover 71% of the original sample. One child was excluded from the study at 12 months of age due to craniosynostosis and mental retardation. No other severe illnesses or malformations were present in the sample.

The majority of those who left the study did so because they had moved abroad or to distant parts of the country. Some left because they lost interest in the study. Four children have died, 2 in traffic accidents at age 5 and 17 respectively and 2 have committed suicide, one girl at age 17 and one boy at age 18.

All forms were originally designed for computerized analyses. Since 1970 the computer analyses are performed at the Department of Pediatrics and Anatomy, University of Göteborg. The antropometric data are stored on discs after several editing procedures. The other data are presently stored in various processing phases.

Growth charts have been constructed and since 1972 are in general use in Sweden in preventive and curative pediatrics. Analyses of distributions of different variables are in progress as a basis of SD-scores applicable to attained size as well as increments that may be applied in clinical work. Analyses of the patterns of changes in body proportions during growth are also in progress. Analyses of the psychological data are presently performed in Stockholm.

PRESENT STATUS OF DATA

	Months						Years																
	1	3	6	9	12	13	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
Examinations and questionnaires																								
Family history - Pregnancy. Birth	v																							
Social form					v		v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	O	O	+
Health-Feeding-Clinical Examination	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v						
Health-Clinical Examination																			v	v	v	v	v	+
Somatic measurements	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
Weight, standing height, sitting height every 3 months																								
Bone age	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	
Signs of puberty															v	v	v	v	v	v	v	v	v	v
Lung volumes																v	v	v	v	v	v	v	v	v
Anthropometric Photos									n	n	n	n	n	n	n									
Somatic measurements of parents	v																							

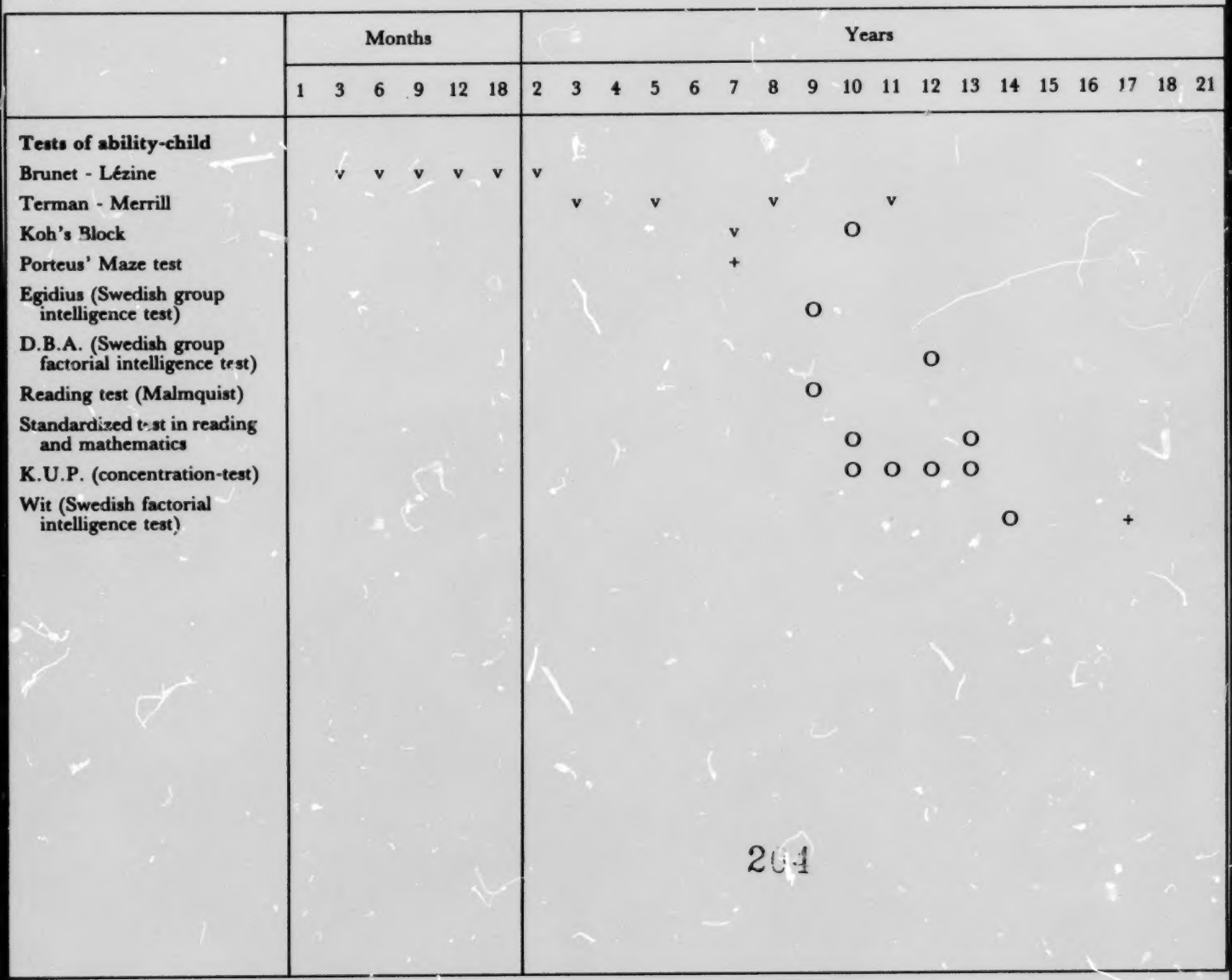
+ + + + + = On original Forms

OOOOO = On Punched Cards

vvvvv = On Tape of Disc

nnnnn = Negatives (Photos)

	Months						Years																
	1	3	6	9	12	18	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
Interviews - child																	+			+	+	+	+	+
Questionnaire - child																								
Leisure activities (Mother and Child together)														+			+		+					
Waern's interest scale																		+		+				
High School Personality (Cattell Questionnaire																				+				
Feeling about things																				+				
What matters																					O			
School and work																					+	+	+	
Generation gap (revised Stug)																							O	
Ratings - child																								
by psychologist		v	v	v	v	v	v	v	v	v	v	v												
by teacher															O			O						
by child																O		O						
Sociometric measurements															O			O						


Months
Years
1 3 6 9 12 18
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 21
Tests of ability-child
Brunet - Lézine
Terman - Merrill
Koh's Block
Porteus' Maze test
Egidius (Swedish group intelligence test)
D.B.A. (Swedish group factorial intelligence test)
Reading test (Malmquist)
Standardized test in reading and mathematics
K.U.P. (concentration-test)
Wit (Swedish factorial intelligence test)

	Months						Years																
	1	3	6	9	12	18	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
Personality tests - child																								
Doll - Play technique (Moore-Ucko)									O		O													
Bestiaire									O	O	O	O	O											
World test										+	+	+												
Rorschach									O	O	O	+	O		+				+				O	
Draw a person									v	v	v	v	v											
Man-Drawing Machover fr 9 years														+		+	+	+	+					
Draw Your Family										+	+	+	+	+		+		+						
Lerner's Blocking test										+	+	+	+	(partly on cards)										
Bene - Anthony Family relation test											O	O												
Rosenzweig frustration test															O		O							
Blacky Picture test														+			+							
Sentence completion (Kälvesten)														+										
T A T																		+						
Osgood's Sem. Diff.																		+						
Barron Welsh Art scale																						+		

	Months						Years															
	1	3	6	9	12	18	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21
Interview - mother																								
Ante-natal, lying-in, etc.	v	v	v	v	v	v	v	v	v	v							+							
Domestic work division																v								
Attitude to upbringing, mother								O																
Attitude to upbringing, father									O															
Questionnaire - mother											v	v	v	v	v	v	v	v	v	v	v	v	v	
Leisure activities (M and C together)															+		+		+					
Attitudes																								
Schaefer - Bell's attitude scale mother									v															
Schaefer - Bell's attitude father									v															
Block's Q - sort mother															O									
Osgood's Sem. Diff. mother																		+						
Ratings - mother		v	v	v	v	v	v	v	v	v	v	v	v				+							
Questionnaire - teacher															O				O					

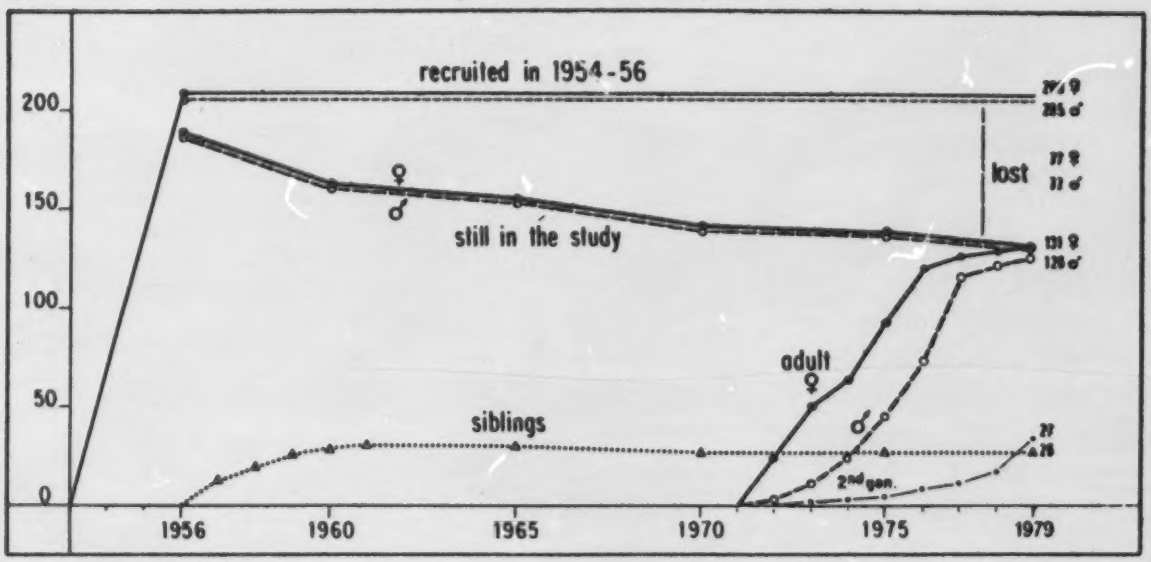
The Zürich Growth and Development Center

Team Members:

Founder: Prof. Guido Fanconi
Head: Prof. Andrea Prader

Year	Physician	Secretary	Psychologist	Mathematician
1954/55	Dr. P. Bovet	Miss H. Schneebeli		
1955/56	Dr. A. Weber			
1956/57	Dr. H. Habich			
1957/58	Mrs. Dr. U. Leupold		Miss M. Berki	
1958/59	Miss Dr. U. Hünerwadel		Mrs. D. Nicolet	
1959/60	Mrs. Dr. E. Heierli			
1960/61	Dr. A. Merminod			
1961/62	Dr. C. Kind			
1962/63	Dr. U. Rumpf			
1963/64	Dr. H. Budliger	Miss M. Willisegger		
1964/66	Dr. H. Fontanellaz		Miss H. Handschin	
1966	Dr. O. Schmelzer		Miss S. Bermann	
1966/67	Dr. G. Bonnard			
1967/68	Dr. D. Schibler		Miss U. Gredig	Ch. Perret
1968/69	Dr. P. Häfliger		Miss E. Lütyens	
1969/70	Dr. J. P. Kind		Mrs. B. Barth	
1970/71	Dr. P. Meier			
1971/72	Dr. T. Töndury			
1972/73	Dr. H. Haldi			
1973/74	Dr. T. Achard			
1974/76	Dr. R. Largo			PD Dr. T. Gasser
1975/76	Dr. H. Bucher			Dr. W. Stützle
1976/79	Dr. M. Weber			Dr. L. Molinari
1976/78	Dr. C. Issler			
1978/79	Dr. R. Largo		Chr. Heldstab	
1979	Dr. U. Issler			

First Longitudinal Growth Study Zürich



THE PRESENT STATUS OF THE DATA

Examinations and questionnaires

Contents	Nr.	Age (years) ½ ⅚ 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
A) Family History - Pregnancy - Birth	1	o
Social Form	0	o o o o o o o o o o o o o o o o o o o o o o o o
Dates of Consultations	—	oooooooooooo o o o o o o o oooooooooo

Interviews with mother

Contents	Nr.	Age (years) ½	¾	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A) 4 Weeks - 5 Years:																											
Fright - Separation - Home Situation - Feeding - Sleep School	5/I	+ 1/12	+	+	+	o	−	o	o 5																		
Elimination and Toilet Training - Habits - Emotional Behaviour	6/II	+ 1/12	+	+	+	o	o	o	o 5																		
Psycho-motor Development Social and Emotional Behaviour - Speech	7/III	+ 1/12	+	+	+	o	o	o	o 5																		
Plays	F/I								o 5																		
B) 6-10 Years:																											
Eating - Sleep - Elimination - Habits - Fear - Speech - Emotional Behaviour	5/II								o 6	o	o	o	o 10														
Fright - Separation - Home Situation - Kindergarten - School	6/III								o 6	o	o	o	o 10														
Social and Emotional Behaviour	7/IV								o 6	o	o	o	o 10														
C) 8-18 Years:																											
Sport - Hobbies - Youth Organisation - Psychiatric Treatment	10										o 8	o	o	o	o	o	o	o	o	o	o 18						
Religion - Leisure - Money	11										o 8	o	o	o	o	o	o	o	o	o	o 18						
D) 11-18 Years:																											
Eating - Sleep - Elimination - Habits - Fear - Speech	13/I													o 11	o	o	o	o	o	o	o 18						
General Behaviour	14/II													o 11	o	o	o	o	o	o	o						
Fright - Separation - Home Situation - School	6/III-IV													o 11	o	o	o	o	o	o	o 18						

Interviews with mother

		Age (years)
Social and Emotional and Mental Behaviour	7/IV-V	
Disagreements - Emotional Behaviour	17/III	
Additional Questions:		
Education - Friendship	A	
Discontentment - Child Parents Interactions	B	
Psychological Tests		
Brunet - Lézine		
Terman - Merrill (Stanford - Test, Form L)		
Doll - Play		
Lückert (Stanford - Test, Form M)		
Goodenough (Man - Drawing)		
Zazzo (Bestiaire)		
Mosaic - Test		
Tree - Test (Drawing)		
Family - Test (Drawing)		
Progressive Marices		
Ipat		
Rosenzweig		
Dominance		
Interest - Test		
AH - 4 - Test		
What is important for you?		
General Interests		

Interviews with Child		Age (years)																											
Contents	Nr.	½	⅝	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A) 12 Years:																											
Memories - Hospitalizations - Separation - School	9/I														o 12												
School	9/II														o												
Future	9/III														o												
General and Rorschach - Qualifications	9/IV														o												
B) 13 Years:																											
School - Daily Performances - Friendship	9/I															o 13											
Qualifications	9/II															o											
C) 14 and 15 Years:																											
School	9/I																o 14	o 15									
Leisure - Friendship - Separation	9/II																o	o									
Qualifications	9/III																o	o									
D) 16 Years:																											
Profession - Education	9/I																		o 16								
School - Professional Purpose	9/II																		o								
Personality - Friendship - Parents	9/III																		o								
E) 17-18 Years:																											
Profession - Education	9/I																			o 17	o 18						
School - Professional Purpose	9/II																			o	o						
Personality - Friendship - Parents	9/III																			o	o						
Smoking - Alcohol - Drugs - Medicaments - Friendships	9/IV																			o	o						
Qualifications	9/V																			o	o						

Interviews with Child	Age (years)	19	20	21	22
F) 19-22 Years:					
Profession - Education	9/I	o	o	o	+
School - Professional Purpose	9/II	o	o	o	+
Smoking - Alcohol - Drugs - Medicaments - Friendships - Home - Money	9/III	o	o	o	+

First Zürich Longitudinal Growth Study

Losses

Age	Probands		Percent of Total	
0- 1	53		12.8	
1- 5	34	87	8.2	21.0
5-10		22		5.3
10-15		26		6.3
15-20		7		1.7
>-10		10		2.4
		152		36.7

Social Classes

Social Class:	?	1	2	3	4	5	Total
Total	71	19	70	227	26	0	413
Losses absolute	63*	4	13	61	11	0	152
percent	41	3	9	40	7	0	
Remaining	8	15	57	166	15	0	274

* 53 lost in 1st year and 5 in 2nd year

Second Zürich Longitudinal Study

The 2nd Zürich longitudinal study was started in October 1974 on the suggestion and with the help of the Division of Neonatology of our hospital (Prof. G. Duc). The purpose is to learn more about growth and development in prematurely born children and to detect neurological and developmental disorders as early as possible.

This study comprises 132 prematurely born children (definition: gestational age shorter than 37 weeks) and 105 healthy full-term infants as a control group. It is planned to follow these children until school age or longer. The full-term group will serve for comparison not only with the premature group but also with the first Zürich longitudinal study.

The children are seen at least once in the neonatal period and thereafter according to the timing of the first longitudinal study. The first month visit (after term) is performed at home.

In addition to the base-line protocol of the CIE-coordinated longitudinal studies, the following questionnaires and examinations are included in this study:

— Information concerning pregnancy, birth and neonatal period.
— Neurological examination of the newborn according to Prechtl (Clinics in Developmental Medicine No. 12, 1964).

— Standardized neurological examination of the at-risk child 0 to 2 years of age.
— Neurological examination according to Touwen (Clinics in Developmental Medicine No. 38, 1970).
— Testing of the psychomotor development according to Griffiths (University of London Press, 1954) (0-2 years of age).
— Measurement of Intelligence: Terman-Merrill (at three years of age).
— Nonverbal test of intelligence according to Snjiders-Omen (at four years of age).
— Illinois psycholinguistic test (at five years of age).
— Testing of visual acuity according to Sheridan (STYCAR Test, Develop. Med. Child Neurol. 16 : 189, 1974).
— Bender Visual Perception Test (at six years of age).
— Testing of hearing using pure-sound audiometry.

Zürich Cross-sectional Study

About 350 prematurely born children will be followed up at the age of five years. This study was started in October 1979 and will continue until 1983. It is the aim of this study to investigate long-term prognosis of prematurely born children and the role of modern perinatology.

The following questionnaires and examinations are carried out:
— Information concerning pregnancy, birth and neonatal period.
— Questionnaires concernings:
  — General health.
  — Psychomotor Development.
  — Behavior disturbances.
  — Psychosocial situation.
— Examinations:
  — Anthropometric measurements.
  — Physical examination.
  — Orthopedic examination.
  — Examination for the presence of minor malformations.
  — Neurological examination according to Touwen.
  — Hamburg - Wechsler - intelligence testing (preschool-form).
  — Testing of the visual acuity according to Sheridan.
  — Testing of the hearing using pure-sound-audiometry.

The Louisville Twin Study, University of Louisville (USA)

Founder: Prof. Frank Falkner
Directors: Prof. Frank Falkner, 1957-1968
Dr. Ronald Wilson, 1968
Psychologists: Dr. Steven Vandenberg, 1961-1968
Dr. Adam Mathewy, 1966

The place and status of the Louisville study needs a special explanation. In 1956 Prof. Frank Falkner took up a position with the University of Louisville. As co-ordinator of the C.I.E. Growth study teams it was natural for him to wish to have his own team, albeit now in the U.S.A., as a part of the co-ordinated C.I.E. effort.

A longitudinal study of monozygous and like-sexed dizygous twins was started soon after in the University's Department of Pediatrics in the Child Development Unit. Clearly, the main purpose of this study was to examine the genetic and environmental weighting upon factors influencing growth and development of children from birth. Thus the study concentrated upon within-pair measurement differences among the twins and for this, measures needed to be, particularly in the psychological measurements, somewhat specialised. However, wherever possible the C.I.E. teams agreed base line of measurements was followed and for somatic growth assessment, this was quite easily fulfilled.

Naturally this study cannot be said to have been a typical member of the family of teams by the very nature of the study's sample of children. But it has been able to contribute strongly towards overall planning, results and conclusions of the teams through its major investigations of nature-nurture on Growth and Development.

Dr. Ronald Wilson became Director of the Child Development Unit and Louisville Twin Study when Professor Falkner moved to another position in 1968. A good number of the somatic and basic psychological measures have been continued on the longitudinal sample which consists approximately of a sample of some 100 pairs of monozygous twins and 100 pairs of like-sexed dizygous twins.

SECTION IV

Cette section comporte:

— la liste, par ordre alphabétique d'auteurs, des travaux publiés par les équipes participant à la recherche coordonnée, ainsi que les publications présentées par les équipes amies lors des réunions de coordination.

Chaque référence est précédée d'un numéro d'indexation et suivie d'un signe entre parenthèses, indiquant la provenance du travail:

(B) Bruxelles, (D) Dakar, (K) Kampala, (Lo) Londres, (Lv) Louisville, (P) Paris, (S) Stockholm, (Z) Zürich, (Ext.) Participants aux Réunions non membres des Equipes.

Les références non suivies de l'initiale de l'équipe sont dues aux groupes amis.

— un index qui comprend successivement:

l'indexation des références selon la classification;

la classification alphabétique des rubriques et mots-clés.

The following bibliography, listing the authors alphabetically, contains the published works of the study groups, plus those papers presented by "friends" at the international coordinating meetings.

The capital letter following each reference indicates the center at which the research work was done.

(B) Brussels, (D) Dakar, (K) Kampala, (Lo) London, (Lv) Louisville, (P) Paris, (S) Stockholm, (Z) Zürich.

When such a capital letter is not found, it means that the paper comes from a "friend" of the regular research teams.

This section contains also an index which includes

— the indexing of references according to the classification;

— the alphabetic classification by subjects and keywords.

Les rapports d'activité des équipes chargées des études sur la croissance et le développement de l'enfant normal ont été publiés par le Centre international de l'Enfance.

Les rapports encore disponibles peuvent être obtenus au C.I.E., Château de Longchamp, Bois de Boulogne - 75016 Paris (France).

The following reports of the activities of the coordinated growth and development teams have been published previously by the International Children's Centre.

They may still be had, if available, by writing to the I.C.C., Château de Longchamp, Bois de Boulogne - 75016 Paris (France).

I 1954 - Paris
II 1955 - Stockholm
III 1956 - Londres
IV 1958 - Bruxelles
V 1960 - Zürich
VI 1962 - Londres
VII 1964 - Paris
VIII 1966 - Stockholm
IX 1968 - Bruxelles (non publié) (not published)
X 1970 - Davos
XI 1972 - Londres
XII 1974 - Paris
XIII 1976 - Rennes
XIV 1979 - Göteborg (non publié) (not published)

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3. ASHIZAWA, K.: Rapport préliminaire de la maturation osseuse des enfants japonais par la méthode de Tanner-Whitehouse. *In:* C.R. 10e Réunion des Equipes chargées des Etudes sur la Croissance et le Développement de l'Enfant normal. Davos, 1970; T.2, pp. 27-28. *C.I.E., Paris, 1971.*

4. ASIEL, M.: Le logement des familles jeunes dans l'agglomération bruxelloise: résultats d'une enquête récente. *Arch. belges Méd. soc.*, 1958, *16* : 1-6. (B)

5. ASIEL, M.: L'influence du travail chez la femme enceinte. *Arch. belges. Méd. soc.*, 1958, *16* : 593-599. (B)

6. ASIEL, M.: La morbidité pendant la première année de vie. *In:* C.R. Réunion des Equipes chargées des Etudes sur la Croissance et le Développement de l'Enfant normal. Zürich, 1960; pp. 27-33. *C.I.E., Paris, 1960.* (B)

7. ASIEL, M.: La morbidité pendant la première année de vie. Constatations faites en milieu urbain et en milieu rural. *Arch. belges Méd. soc.*, 1961, *19* : 357-376. (B)

8. ASIEL, M.: Comparaison des enfants d'une région rurale et d'un quartier urbain. Les absences du foyer. *Arch. belges Méd. soc.*, 1964, *22* : 359-390. (B)

9. ASIEL, M.: Considérations sur l'utilisation des méthodes de Greulich et Pyle et de Tanner pour l'évaluation de la maturation osseuse d'un échantillon de garçons âgés de cinq à neuf ans. *In:* C.R. Réunion des Equipes chargées des Etudes sur la Croissance et le Développement de l'Enfant normal. Stockholm, 1966; T.1, pp. 53-59. *C.I.E., Paris, 1967.* (B)

10. AYNSLEY-GREEN, A.; ZACHMANN, M.; ILLIG, R.; RAMPINI, S. & PRADER, A.: Congenital bilateral anorchia in childhood: a clinical, endocrine and therapeutic evaluation of 21 cases. *Clin. Endocr.*, 1976, *5* : 381-391. (Z)

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CLASSIFICATION ET INDEX — CLASSIFICATION AND INDEX

1. Ouvrages et articles généraux — Books and general articles:

1.1 Ouvrages généraux — General Books:
120, 132, 136, 138, 158, 161, 162, 166, 196, 201, 304, 460, 578bis, 673, 722, 731, 735, 738, 739, 785, 792, 793, 797, 859, 860, 865.

1.2 Articles généraux — General Articles:

1.2.1 Croissance, généralités — Growth, general:
114, 127, 157, 163, 188, 198, 201, 208, 295, 373, 431, 435, 471, 474, 475, 477, 482, 490, 583, 600, 617, 636, 654, 656, 657, 658, 693, 736, 737, 774, 784, 786, 790, 794, 798, 802, 814, 829, 830, 833, 856, 863, 864, 877, 912.

1.2.2 Présentation de résultats, observations de populations, études nationales de croissance — Results, population findings, nation growth studies:
12, 15, 36, 59, 72, 73, 92, 109, 143, 149, 203, 225, 232, 234, 249, 293, 298, 366, 371, 374, 377, 378, 379, 380, 382, 385, 422, 439, 443, 478, 493, 499, 500, 501, 557, 581, 614, 621, 709, 711, 748, 778, 801, 804, 815, 832, 850, 898, 899, 900, 901, 902, 903, 904, 944, 946.

1.2.3 Comparaisons internationales — International comparative studies:
122, 129, 134, 322, 324, 327, 330, 485, 486, 831.

1.2.4 Enseignements des notions de croissance et de développement. Axes de recherche — Teaching concepts of growth and development. Lines of research:
148, 166, 182, 202, 473, 478, 486, 889.

1.2.5 Développement de l'enfant: utilisation en santé publique — Child development data: use in public health:
122, 182, 197, 202, 367, 488, 641, 699, 861, 896, 906.

1.3 Standards de croissance — Growth standards:
15, 30, 38, 39, 69, 73, 92, 128, 143, 149, 151, 203, 275, 282, 293, 385, 476, 493, 629, 711, 712, 721, 743, 761, 777, 801, 817, 818, 841, 843, 844, 845, 850, 854, 862, 872, 873, 895, 898, 899, 900, 901, 902, 903, 918.

2. Méthodologie des études de croissance — Methodology of growth studies:

2.1 Généralités — General:
58, 61, 114, 115, 117, 118, 133, 136, 138, 142, 144, 206, 207, 340, 341, 470, 485, 747, 878, 894, 947.

2.1.1 Méthodologie des enquêtes longitudinales — Methodology of longitudinal studies:
120, 123, 126, 142, 172, 259, 271, 272, 289, 458, 485, 528, 675, 677, 881, 889, 890.

2.1.1.1 Croissance physique — Somatic:
106, 118, 123, 176, 258, 259, 262, 263, 362, 754.

2.1.1.2 Développement psychologique — Psychologic:
86, 106, 179, 212, 253, 255, 257, 313, 316, 317, 318, 323, 331, 335, 338, 344, 388, 528, 530, 542, 578, 666, 696, 698.

2.2 Méthodologie d'étude des paramètres somatiques — Methodology for studying somatic characteristics:

2.2.1 Généralités — General:
115, 117, 128, 136, 140, 141, 162, 176, 407, 645, 714, 774.

2.2.2 Etablissement et utilisation des standards — The setting up and and use of standards:
143, 148, 149, 170, 266, 284, 382, 456, 629, 713, 717, 730, 862.

2.2.3 Appareillage, équipement et techniques diverses: somatotypes (photographies), radiographies (sauf maturation osseuse) — Apparatus, equipment, techniques, photography, radiography (except bone maturation):
102, 116, 153, 305, 352, 456, 572, 622, 751, 768, 769, 770, 773, 776, 799.

2.2.4 Variations analytiques — Variations in analysis:
162, 262, 263, 264, 766, 876, 911.

2.3 Méthodologie d'étude de la maturation sexuelle et du développement génital — Methodology of studying sexual maturation and genital development:
192, 209, 383, 446, 464, 603, 779, 932.

2.4 Méthodologie d'étude de la maturation osseuse et dentaire — Methodology of studying bone and dental maturation:

2.4.1 Généralités — General:
53, 119, 130, 169, 349, 462, 466, 715, 719, 723, 778, 782, 847, 866, 867, 868, 869, 870, 875, 888.

2.4.2 Méthode de Greulich et Pyle — Greulich-Pyle:
9, 204, 205, 521.

2.4.3 Méthode de Tanner et Whitehouse — Tanner-Whitehouse:
9, 463, 521, 778, 782, 788, 826, 827, 852, 858.

2.4.4 Autres méthodes — Others:
463, 467, 646, 722, 726, 727, 728, 746, 868, 869, 873.

2.4.5 Vitesse de maturation osseuse — Velocity of bone maturation:
432, 465, 723, 728.

2.4.6 Méthodologie d'étude de la maturation dentaire — Dental maturation studies:
88, 89.

2.5 Méthodologie d'étude du développement psychologique — Methodology of psychologic studies:

2.5.1 Généralités — General:
136, 138, 179, 225, 309, 310, 313, 316, 317, 318, 405, 408, 550.

2.5.2 Mesure de l'intelligence — Measurements of intelligence:
19, 52, 211, 212, 219, 223, 224, 227, 228, 238, 297, 312, 321, 338, 339, 342, 508, 553, 578, 662.

2.5.3 Tests de personnalité — Personality tests:
401, 424, 507, 513, 530, 531, 532, 907.

2.6 Classification sociale — Social classification:
136, 138, 267, 268, 269, 274, 276, 292, 378, 520, 943, 945.

2.7 Techniques mathématiques et statistiques — Mathematical and statistical techniques:

2.7.1 Formulation mathématique de la croissance — Mathematical formulation of growth:
264, 419, 469, 579, 580, 631, 759, 760.

2.7.2 Statistiques — Statistics:
258, 259, 261, 263, 266, 362, 502, 503.

2.7.3 Utilisation de l'informatique — Use of computerized data:
63, 65, 622, 740, 741, 742.

2.7.4 Enregistrement et analyse des données — Data recording and processing:
64, 65, 206, 207, 258, 259, 261, 262, 263, 273, 376, 381, 550, 763, 876.

2.8 Etudes sur les jumeaux — Twin studies:
2, 45, 46, 121, 126, 150, 154, 155, 159, 160, 190, 199, 505, 506, 507, 509, 512, 567, 915, 916, 918, 919, 920, 921, 922, 924.

2.9 Etudes chez l'animal — Experimental animal studies:
343, 348, 349, 350, 351, 352, 789, 813, 913, 914.

3. Observation du développement physique (voir aussi 1.2.3 et 1.3.) — Observations of physical growth (see also 1.2.3 and 1.3.):

3.1 Développement statural — Height growth:
17, 143, 184, 214, 441.

3.1.1 Taille — Height:
99, 103, 265, 278, 282, 293, 306, 382, 469, 476, 493, 614, 638, 743, 752, 832, 850, 911.

3.1.2 Segments — Segmental:
57, 96, 99, 100, 101, 300, 305, 456, 469, 611, 705, 706, 752, 911.

3.1.3 Diamètre — Diameters:
469, 653, 752.

3.1.4 Vitesse de croissance — Growth velocity:
173, 440, 527, 614, 638, 801, 804, 850.

3.2 Développement pondéral, composition du corps — Weight growth, body composition:

3.2.1 Poids — Weight:
103, 143, 214, 275, 282, 293, 306, 382, 476, 493, 614, 651, 743, 801, 832, 850.

3.2.2 Relation poids/taille — Ratio of weight to height:
895.

3.2.3 Tissu adipeux. Plis cutanés. Masse du tissu graisseux. — Adipose tissue. Skin-folds. Fat mass:
41, 55, 56, 69, 307, 491, 494, 572, 612, 613, 758, 769, 770, 773, 787, 799, 810, 843, 854.

3.2.4 Obésité (voir aussi 3.9.2) — Obesity (see also 3.9.2.):
91, 651, 767, 891.

3.2.5 Composition du corps — Body composition:
41, 116, 145, 153, 178, 571, 767, 799, 810.

3.2.6 Volume et surface du corps — Body volume and surface:
131, 152.

3.3 Maturation osseuse et dentaire — Bone and dental maturation:

3.3.1 Généralités — General:
53, 119, 130, 180, 432, 438, 448, 453, 566, 659, 727, 728, 734, 738, 740, 741, 742, 847, 870.

3.3.2 Standards. Observations de populations — Standards. Population observations:
3, 13, 54, 204, 205, 369, 438, 462, 467, 496, 497, 521, 522, 523, 558, 561, 562, 609, 826, 827, 828, 852, 872.

3.3.3 Comparaisons de populations — Population comparisons:
462, 492, 521, 563.

3.3.4 Maturation osseuse du nourrisson — Infant bone maturation:
205, 561, 872.

3.3.5 Maturation osseuse de l'enfant d'âge préscolaire — Preschoolchild, bone maturation:
205, 872.

3.3.6 Maturation osseuse de l'écolier et de l'adolescent — School age and adolescent, bone maturation:
9, 205, 299, 347, 369, 445, 521, 522, 523, 558, 729, 732, 733.

3.3.7 Ossification (croissance osseuse en épaisseur — Ossification (bone thickness growth):
27, 90, 113, 810, 854, 899.

3.3.8 Anomalies morphologiques des os — Structural bone anomalies:
250, 251, 252, 253, 359, 427, 430.

3.3.9 Maturation dentaire — Dental maturation:
87, 88, 89, 124, 744, 871.

3.4 Puberté normale (voir aussi 5.5.) — Normal puberty (see also 5.5.):

3.4.1 Généralités — General:
110, 111, 178, 183, 209, 299, 300, 303, 347, 364, 384, 421, 434, 436, 445, 446, 447, 448, 449, 452, 453, 461, 484, 504, 523, 599, 619, 634, 694, 729, 750, 785, 792, 805, 816, 820, 835, 839, 841, 850, 874.

3.4.2 Déroulement de la puberté chez la fille. Ménarche — Development of puberty in girls. Menarche:
33, 55, 56, 74, 99, 209, 303, 368, 386, 433, 442, 450, 451, 560, 649, 652, 653, 690, 725, 752, 779, 803, 831, 902.

3.4.3 Déroulement de la puberté chez le garçon — Development of puberty in boys:
209, 303, 423, 437, 442, 594, 608, 650, 932.

3.5 Développement de la tête, de la face, du cerveau. Périmètre crânien — Growth of head, face, brain. Cranial perimeter:
40, 278, 306, 382, 411, 415, 429, 524, 703, 775.

3.6 Développement du thorax et de la fonction respiratoire — Growth: thorax and respiratory function:
60, 71, 110, 111, 751, 908.

3.7 Pigmentation. Couleur des yeux et des cheveux — Pigmentation. Color of eyes and hair:
514, 515.

3.8 Développement sensoriel — Sensory development:
414.

3.9 Prédictions — Predictions:

3.9.1 Prédiction de la taille — Height:
21, 213, 347, 370, 420, 644, 707, 772, 844, 845, 852, 858, 941.

3.9.2. Prédiction de la corpulence — Weight:
91, 307, 420, 459, 575, 576, 651, 772, 891.

3.9.3. Prédiction de l'âge de la ménarche — Menarche onset:
450, 457.

4. Observation du développement psychomoteur et psychologique — Observation of psychomotor and psychologic development:

4.1 Généralités — General:
81, 179, 184, 313, 316, 393, 395, 400, 673, 675, 700, 704.

4.2 Développement psychomoteur et intellectuel (voir aussi 4.3.) — Psychomotor and intellectual development (see also 4.3.):
83, 84, 86, 105, 211, 212, 216, 217, 220, 222, 229, 230, 231, 232, 233, 234, 244, 249, 315, 332, 336, 337, 338, 339, 342, 346, 358, 392, 399, 410, 441, 506, 508, 513, 541, 555, 556, 661, 696, 697, 698, 923.

4.3 Age de la marche — Age of onset of walking:
324, 328, 330, 573, 574, 660.

4.4 Langage. Lecture — Speech. Reading:
509, 511, 512, 541.

4.5 Développement de la personnalité — Personality development:
46, 254, 255, 256, 257, 315, 392, 403, 424, 507, 513, 516, 517, 543, 544, 663, 682, 684, 685, 686, 688, 755, 887.

4.6 Comportement — Behaviour:

4.6.1 Sommeil — Sleep:
94, 390, 394, 529.

4.6.2 Propreté. Enurésie — Toilet training. Enuresis:
94, 322, 326, 330, 387, 412, 413, 416, 417, 418, 674.

4.6.3 Jeu — Play:
531, 532, 533, 885.

4.7 Attitudes — Attitudes:
365, 398, 550, 551, 882, 885.

4.7.1 Attitudes dans l'adolescence — During adolescence:
24, 25, 67, 404, 545, 548, 551.

4.8 Prédictions (Intelligence, personnalité) — Prediction of intelligence, personality:
254, 255, 256, 257, 312, 321, 332, 333, 345, 516, 555, 556, 568, 569, 682.

4.9 Relations développement physique/développement psychologique — Relations of physical to psychologic development:
50, 51, 334, 441, 695.

5. Développement et problèmes spécifiques aux différentes périodes de la vie — Development and special problems at various periods:

5.1 Grossesse. Caractéristiques de naissance — Pregnancy. Birth characteristics:
5, 150, 155, 156, 174, 188, 189, 193, 194, 220, 423, 426, 627, 708, 720, 818, 824, 825, 826, 832, 836.

5.2 Nourrisson (voir aussi 3.3.4.) — Infant (see also 3.3.4.):
69, 105, 128, 129, 188, 189, 193, 194, 214, 222, 234, 275, 278, 282, 306, 379, 411, 519, 559, 581, 613, 648, 673, 708, 783.

5.3 Enfant d'âge préscolaire (voir aussi 3.3.5.) — Preschool age (see also 3.3.5):
17, 109, 214, 234, 295, 306, 379, 475, 477, 519, 648, 665.

5.4 Ecolier. Scolarité (voir aussi 3.3.6.) — Schoolage. School attendance (see also 3.3.6.):
29, 73, 361, 363, 364, 537, 538, 539, 545, 691, 692, 743, 781, 793, 906.

5.5 Adolescent (voir aussi 3.3.6. - 3.4.2 - 3.4.3 - 4.7.1.) — Adolescent (see also 3.3.6. - 3.4.2. - 3.4.3. - 4.7.1.):
31, 32, 35, 99, 174, 300, 405, 419, 428, 449, 610, 613, 619, 704, 765, 785, 792, 809, 810, 816, 820, 834, 837, 853, 855, 879, 880, 905, 907.

6. Facteurs du développement — Factors in development:

6.1 Hérédité (voir aussi 2.8.) — Heredity (see also 2.8):

6.1.1 Généralités — General:
112, 154, 286, 308, 336, 372, 771, 780, 892, 893.

6.1.2 Facteurs ethniques — Ethnic factors:
112, 328, 498, 748, 802, 839, 848.

6.1.3 Facteurs génétiques du développement psychologique — Genetic factors in psychologic development:
510, 511, 512.

6.2 Corrélation intra-familiales — Intrafamilial factors:
44, 91, 121, 410, 637, 779, 817, 818, 821, 824, 825, 844, 845.

6.3 Environnement — Environment:

6.3.1 Généralités — General:
36, 112, 265, 698, 699, 849.

6.3.2 Environnement et croissance physique. Généralités — Environment and physical growth. General:
103, 265, 281, 372, 718.

6.3.3 Environnement et développement psychologique. Général — Environment and psychologic development. General:
22, 221, 224, 225, 226, 229, 233, 237, 241, 242, 245, 319, 320, 330, 336, 397, 541, 568, 570, 577.

6.4 Rôle des différentes composantes de l'environnement (sauf nutrition) — Role of environmental factors (exclusing nutrition):

6.4.1 Environnement socio-économique — Socio-economic factors:
22, 28, 36, 52, 103, 221, 224, 225, 229, 233, 236, 245, 259, 268, 269, 281, 283, 285, 287, 288, 290, 291, 301, 319, 320, 329, 330, 336, 397, 568, 570, 698, 699, 748, 943.

6.4.2 Environnement familial et affectif — Family and emotional factors:

6.4.2.1 Généralités — General:
85, 104, 107, 186, 222, 233, 239, 240, 241, 242, 246, 248, 678, 679, 683, 697.

6.4.2.2 *Travail maternel. Garde de l'enfant — Maternal work. Child arrangements:*
5, 16, 533, 534, 535, 540, 546, 547, 664, 668, 687.

6.4.2.3 Adoption — Adoption:
680.

6.4.2.4. Ruptures familiales. Divorces — Broken homes. Divorce:
664, 681.

6.4.3 Environnement culturel — Cultural environment:
21, 221, 226, 233, 240, 242, 245, 246, 248.

6.4.4 Logement. Milieu urbain/rural — Housing. Urban, rural:
4, 7, 8, 221, 226, 235, 237, 242, 269, 279, 374.

6.4.5 Environnement climatique, saisons — Climate. Seasons:
444, 454, 495.

6.4.6 Sports — Sports:
409, 795.

6.4.7 Accélération séculaire de la croissance — Secular growth acceleration:
489, 718, 797, 800, 806, 811, 831.

6.4.8 Rattrapage de croissance — Catch-up growth:
20, 40, 302, 584, 616, 749, 897, 913.

6.5 Nutrition et croissance — Nutrition and growth:

6.5.1 Généralités — General:
41, 151, 177, 180, 187, 191, 197, 200, 322, 459, 479, 483, 489, 576, 642, 670, 671, 861, 904, 906.

6.5.2 Allaitement maternel — Breast-feeding:
270, 322, 330, 389, 459, 667, 670, 671, 689, 904.

6.5.3 Malnutrition — Malnutrition:
20, 62, 77, 78, 79, 80, 82, 197, 215, 218, 406, 480, 494, 557, 584, 601, 642, 749, 883, 897, 913, 914.

6.5.4 Rachitisme — Rickets:
72, 884.

7. Pathologie et croissance — Pathology and growth:

7.1 Généralités — General:
135, 171, 460, 584, 856, 941.

7.2 Croissance sub-normale — Subnormal growth:
171, 362, 598, 655, 658, 730, 819, 845.

7.3 Retards et avances de croissance et de puberté — Delayed and precocious puberty and growth:

7.3.1 Généralités — General:
446, 594, 598, 615, 620, 630, 632, 655, 819, 822, 940.

7.3.2 Excès de la taille chez la fille — Excess height in girls:
455, 604, 607, 618, 738, 933.

7.3.3 Excès de la taille chez le garçon — Excess height in boys:
604, 607, 618, 738, 937.

7.3.4 Insuffisance de taille chez la fille — Inadequate height in girls:
564, 565, 845, 935.

7.3.5 Insuffisance de taille chez le garçon — Inadequate height in boys:
356, 468, 564, 565, 701, 845, 935.

7.3.6 Retards pubertaires — Delayed puberty:
26, 354, 357, 594, 608, 620, 927.

7.3.7 Avances pubertaires — Precocious puberty:
37, 44, 75, 97, 98, 213, 594, 640, 756, 908, 910.

7.4. Anomalies orthopédiques — Orthopedic anomalies:

7.4.1 Anomalies orthopédiques congénitales — Congenital:
756.

7.4.2 Anomalies orthopédiques acquises — Acquired:
97, 98, 100, 181, 640, 756.

7.4.3 Syndromes — Syndromes:
252, 812, 840.

7.5 Aberrations chromosomiques — Chromosome anomalies:

7.5.1 Syndrome de Turner — Turner's syndrome:
43, 44, 213, 552, 822.

7.5.2 Syndrome de Klinefelter — Klinefelter's syndrome:
44, 705, 706.

7.5.3 Trisomie 21 — Trisomy 21:
44.

7.5.4 Hermaphrodisme et pseudo-hermaphrodisme — Hermaphroditism and pseudo-hermaphroditism:
702.

7.6 Glandes endocrines — Endocrines:

7.6.1 Généralités — General:
296, 566, 598, 796, 807.

7.6.2 Hypophyse — Pituitary:

7.6.2.1 Hypopituitarisme. Déficit en hormone de croissance. — Hypopituitarism, growth hormone deficiency:
11, 343, 582, 585, 586, 587, 590, 592, 593, 597, 605, 624, 625, 626, 627, 633, 647, 822, 838, 842, 857, 925, 928, 930, 931, 936, 942.

7.6.2.2 Hormone de croissance, effets, dosage, taux — Growth hormone: effects, dosage, levels:
343, 353, 356, 585, 587, 591, 592, 595, 596, 628, 739, 823, 857, 925, 929.

7.6.2.3 Hormone de croissance, utilisation thérapeutique — Growth hormone in therapy:
11, 66, 68, 355, 356, 525, 526, 582, 586, 587, 588, 589, 592, 593, 597, 605, 625, 635, 762, 812, 822, 857, 928.

7.6.3 Surrénales — Adrenals:
34, 42, 44, 76, 410, 623, 639.

7.6.4 Gonades — Gonads:
10, 739.

7.6.5 Thyroïde — Thyroid:
302, 343, 726.

7.6.6 Parathyroïdes. Pseudohypoparathyroïdie — Parathyroid. Pseudohypoparathyroidism:
909.

7.6.7 Thérapeutiques endocriniennes (sauf hormone de croissance: voir 7.6.2.3.) — Endocrinotherapy (excluding growth hormone: see 7.6.2.3.):
11, 34, 75, 354, 464, 468, 552, 604, 623, 826, 827.

7.6.8 Pancréas — Pancreas:
908.

7.7 Affections viscérales diverses — Various organs-pathology:

7.7.1 Maladies rénales. Insuffisance rénale chronique. Hémodialyse — Renal, Chronic renal disease. Hemodialysis:
47, 48.

7.7.2 Maladies cardiaques — Cardiac diseases:
18.

7.7.3 Maladies héréditaires du métabolisme — Inborn errors of metabolism:
250.

7.7.4 Maladies digestives. Alimentation parentérale — Gastrointestinal diseases. Parenteral feeding:
20, 601, 749.

7.7.5 Diabète — Diabetes mellitus:
23, 710, 716.

7.8 Anomalies périnatales — Perinatal anomalies:
70, 147, 160, 185, 627.

7.8.1 Prématurité. Avenir des enfants prématurés — Prematurity. Outcome of prematures:
30, 38, 70, 93, 151, 189, 193, 411, 415, 724, 832.

7.8.2 Hypotrophie fœtale — Fetal hypotrophy, small-for-date:
39, 40, 165, 189, 193, 194, 822.

7.8.3 Exsanguino-transfusion — Exchange transfusion:
38.

7.8.4 Anoxie fœtale — Fetal anoxia:
886.

8. Morbidité - mortalité (études diverses) — Morbidity - mortality (various studies):

8.1 Mortalité infantile — Infant mortality:
164, 167, 185.

8.2 Etudes de morbidité, généralités — Morbidity, general:
6, 7, 8, 14, 93, 279, 280, 375, 581.

8.3 Enfants à risque, dépistage — Children at risk. Screening:
1, 182, 185, 487, 643.

8.4. Accidents — Accidents:
175, 554.

8.5 Handicaps, guidance — Handicaps, guidance:
669.

8.6 Affections respiratoires — Respiratory illnesses:
518.

8.7 Allergie — Allergy:
210.

8.8 Caries dentaires — Dental caries:
360.

9. Origine géographique des études de croissance (voir aussi 1.) — Geographic regions of the studies (see also 1.):

9.1 Amérique du Nord — North America:

9.1.1 Etats-Unis d'Amérique — U.S.A.:
143, 149, 492.

9.1.2 Canada — Canada:
87, 88, 89.

9.2 Amérique Latine — Latin America:

9.2.1 Argentine — Argentina:
72, 73.

9.2.2 Chili — Chile:
581.

9.2.3 Cuba — Cuba:
366, 367.

9.2.4 Jamaïque — Jamaica:
438.

9.2.5 Mexique — Mexico:
203.

9.2.6 Venezuela — Venezuela:
422.

9.3 Afrique Noire — Black Africa:

9.3.1 Ouganda — Uganda:
77, 78, 80, 81, 216 à 249.

9.3.2 Sénégal — Senegal:
19, 31, 32, 33, 34, 74, 406, 491 à 497, 499, 500, 501, 504, 521, 522, 523, 553, 641, 704, 743 à 746, 945.

9.3.3 Zambie — Zambie:
243, 244.

9.4 Afrique du Nord - Moyen Orient — North Africa, Middle East:

9.4.1 Israël — Israel:
405, 748.

9.4.2 Tunisie — Tunisia:
36, 301, 901, 903.

9.4.3 Turquie — Turkey:
557 à 561.

9.5. Asie — Asia:

9.5.1 Japon — Japan:
3.

9.6 Europe — European region:

9.6.1 Allemagne (République Fédérale) — German Federal Republic:
38, 39, 40, 298.

9.6.2 Belgique — Belgium:
9, 241, 275, 277 à 280, 282, 293, 673, 695, 698, 898, 899, 900, 902, 904, 943.

9.6.3 Bulgarie — Bulgaria:
708.

9.6.4 Espagne — Spain:
462, 467.

9.6.5 Finlande — Finland:
12, 13, 15, 368, 369.

9.6.6 France — France:
476, 478, 648 à 652, 695, 709, 711, 712, 721, 736, 943.

9.6.7 Hongrie — Hungary:
831.

9.6.8 Italie — Italy:
92, 185, 562, 563.

9.6.9 Norvège — Norway:
753.

9.6.10 Pays-Bas — The Netherlands:
512, 895, 897

9.6.11 Pologne — Poland:
407, 944.

9.6.12 Royaume-Uni — United Kingdom:
59, 305, 338, 339, 342, 525, 647, 777, 783, 787, 801, 804, 818, 820, 821, 832, 850, 943.

9.6.13 Suède — Sweden:
24, 25, 185, 373, 374, 377 à 380, 385, 392, 399, 421, 872.

9.6.14 Suisse — Switzerland:
54, 204, 205, 306, 386, 519, 611, 612, 614, 695, 943.

9.6.15 Tchécoslovaquie — Czechoslovakia:
28, 371, 372, 637, 946.

9.6.16 U.R.S.S. — U.S.S.R.:
524.

INDEX ALPHABÉTIQUE (SUJETS)*

A

Aberrations chromosomiques 7.5.
Accélération séculaire de la croissance 6.4.7
Accident 8.4.
Adolescent
— Attitude 4.7.1.
— Développement et problèmes spécifiques 5.5.
— Maturation osseuse 3.3.6.
— Puberté
—, avance 7.3.7.
—, déroulement 3.4.
—, retard 7.3.6.
Adoption 6.4.2.3.
Afrique Noire 9.3.
Afrique du Nord 9.4.
Age préscolaire 5.3.
— Maturation osseuse 3.3.5.
Age scolaire 5.4.
— Maturation osseuse 3.3.6.
Alimentation parentérale 7.7.4.
Allaitement maternel 6.5.2.
Allemagne 9.6.1.
Allergie 8.7.
Amérique Latine 9.2.
Amérique du Nord 9.1.
Animal, études sur 2.9.
Anomalie orthopédique 7.4.
Anoxie fœtale 7.8.4.
Appareillage 2.2.3.
Argentine 9.2.1.
Asie 9.5.
Attitude 4.7.
— Adolescent 4.7.1.

B

Belgique 9.6.2.
Bulgarie 9.6.3.

C

Canada 9.1.2.
Caraïbes 9.2.
Carie dentaire 8.8.
Cerveau, développement 3.5.
Cheveux, couleur 3.7.
Chili 9.2.2.
Classification sociale 2.6.
Climat 6.4.5.
Comportement 4.6.
Corps
— Composition 3.2.5.
— Surface 3.2.6.
— Volume 3.2.6.
Corpulence, prédiction 3.9.2.
Crâne, périmètre 3.5.
Croissance

* Les numéros renvoient aux références du plan d'indexation et non pas aux numéros des publications.

— Accélération séculaire 6.4.7.
— Avance 7.3.
— Développement pondéral 3.2.
— statural 3.1.
— Enquête longitudinale 2.1.1.
— Formulation mathématique 2.7.1.
— Généralités 1.
— Méthodologie des études 2.
— et Nutrition 6.5.
— osseuse en épaisseur 3.3.7.
— et Pathologie 7.
— physique et environnement 6.3.2.
— Rattrapage 6.4.8.
— Retard 7.3.
— Standards 1.3.
Etablissement et utilisation 2.2.2.
— sub-normale 7.2.
— Vitesse de 3.1.4.
Cuba 9.2.3.

D

Dent, carie 8.8.
— Maturation 3.3.9.
— , méthode d'étude 2.4.6.
Développement
— aux différentes périodes de la vie 5.
— Environnement 6.3.2.
— Etude du —: utilisation en santé publique 1.2.5.
— Facteurs de — 6.
— — ethniques 6.1.2.
— — génétiques 6.1.3.
Développement génital
— Méthodologie d'étude 2.3
Développement physique 1.2.1., 1.2.2., 1.3., 3.
— et Développement psychomoteur, relations 4.9.
— Méthodologie des enquêtes longitudinales 2.1.1.1.
Développement psychologique, psychomoteur 4.
— et Développement physique, relations 4.9.
— et Environnement 6.3.3.
— Méthodologie des enquêtes longitudinales 2.1.1.2.
— Méthodologie d'étude 2.5.
Développement sensoriel 3.8.
Diabète 7.7.5.
Diamètre 3.1.3.
Données, enregistrement et analyse 2.7.4.

E

Ecolier (voir âge scolaire)
Enquêtes longitudinales 2.1.1.
— Croissance physique, méthodologie des — 2.1.1.1.
— Développement psychologique, méthodologie des — 2.1.1.2.
Enregistrement des données 2.7.4.
Enurésie 4.6.2.
Environnement 6.3., 6.4.
— affectif 6.4.2.
— climatique 6.4.5.
— et Croissance physique 6.3.2.
— culturel 6.4.3.
— et Développement psychologique 6.3.3.
— familial 6.4.2.
— socio-économique 6.4.1.
Espagne 9.6.4.
Ethnie 6.1.2.
Europe 9.6.
Exsanguino-transfusion 7.8.3.

F

Face, développement 3.5.
Facteurs de développement 6.
Famille
— Corrélation entre les paramètres somatiques 6.2.
— Environnement 6.4.2.
— Rupture 6.4.2.4.
Fibrose kystique 7.6.8.
Fille
— Puberté 3.4.2., 5.5.
— , avance 7.3.7.
— , retard, 7.3.6.
— Taille, excès 7.3.2.
— , insuffisance 7.3.4.
Finlande 9.6.5.
Fœtus, anoxie 7.8.4.
France 9.6.6.

G

Garçon
— Puberté 3.4.3, 5.5
— , avance 7.3.7.
— , retard 7.3.6.
— Taille, excès 7.3.3.
— , insuffisance 7.3.5.
Garde de l'enfant 6.4.2.2.
Génétique
— Chromosome, aberration 7.5.
— Facteurs du développement psychologique 6.1.3.
Glandes endocrines 7.6.
Gonades 7.6.4.
Greulich et Pyle, méthode de 2.4.2.
Grossesse 5.1.
Guidance 8.5.

H

Handicap 8.5.
Hérédité 6.1.
Hermaphrodisme 7.5.4.
Hongrie 9.6.7.
Hormone de croissance, déficit 7.6.2.1.
— Dosage 7.6.2.2.
— Effets 7.6.2.2.
— Utilisation thérapeutique 7.6.2.3.

H

Hypophyse 7.6.2.
Hypopituitarisme 7.6.2.1.
Hypotrophie fœtale 7.8.2.

I

Indicateur de santé 1.2.5.
Informatique 2.7.3.
Insuffisance rénale chronique 7.7.1.
Intelligence, mesure de l' 2.5.2.
(voir aussi Développement psychologique et psychomoteur)
Israël 9.4.1.
Italie 9.6.8.

J

Jamaïque 9.2.4.
Japon 9.5.1.
Jeu 4.6.3.
Jumeaux 2.8.

K

Klinefelter, syndrome de 7.5.2.

L

Langage 4.4.
Lecture 4.4.
Logement 6.4.4.

M

Maladie cardiaque 7.7.2.
— digestive 7.7.4.
— héréditaire du mébabolisme 7.7.3.
— rénale 7.7.1.
Malnutrition 6.5.3.
Marche, âge de la 4.3.
Masse grasse 3.2.3.
Mathématique, formulation 2.7.1.
Maturation
— dentaire 3.3.9.
— , méthodes d'étude 2.4.6.
— osseuse 3.3
— , méthodes d'étude 2.4.5.
— sexuelle
— , méthodes d'étude 2.3 (voir aussi Puberté)
Ménarche 3.4.2., 3.9.3.
Méthodologie
— Etudes de croissance 2.
— Etude du développement psychologique 2.5.
— Etude de la maturation dentaire 2.4.6.
— Etude de la maturation osseuse 2.4.
— Etude de la maturation sexuelle 2.3.
Mexique 9.2.5.
Mode de garde de l'enfant 6.4.2.2.
Morbidité 8.
Mortalité infantile 8.1.
Moyen-Orient 9.4.
Mucoviscidose 7.6.8.

N

Naissance, caractéristiques de 5.1.
Norvège 9.6.9.
Nourrisson
— Développement et problèmes spécifiques 5.2.
— Maturation osseuse 3.3.4.
Nouveau-né 5.1.
— Anomalies périnatales 7.8.
Nutrition et croissance 6.5.

O

Obésité 3.2.4.
Observation de population 1.2.2., 1.2.3, 3.3.2, 3.3.3.
Œil, couleur 3.7.
Orthopédiques, anomalies 7.4.
Os
— Anomalies morphologiques 3.3.8.
— Croissance en épaisseur 3.3.7.
— Maturation 2.4.5., 3.3.
Ossification 3.3.7.
Ouganda 9.3.1.

P

Paramètres somatiques
— Méthodologie d'étude 2.2.
Parathyroïdes 7.6.6.
Pathologie et croissance 7.
Pays-Bas 9.6.10.
Périmètre brachial 3.1.3.
— — crânien 3.5.
— — thoracique 3.6.
Périnatale, anomalie 7.8.
— Caractéristiques de naissance 5.1.
Personnalité
— Dévelopement 4.5.
— Prédiction 4.8.
— Test 2.5.3.
Photographie 2.2.3.
Physique, développement (voir Développement physique)
Pigmentation 3.7.
Plis cutanés 3.2.3.
Poids 3.2.1.
— Relation poids/taille 3.2.2.
Pologne 9.6.11.
Population, observation 1.2.2., 1.2.3, 3.3.2.
— Maturation osseuse et dentaire, comparaison de — 3.3.3.
Poumons 3.6.
Prédiction
— Corpulence 3.9.2.
— Intelligence. Personnalité 4.8.
— Ménarche 3.9.3.
— Taille 3.9.1.
Prématuré, prématurité 7.8.1.
Préscolaire, âge (voir Age préscolaire)
Propreté 4.6.2.
Pseudohypoparathyroïdie 7.6.6.
Psychologique, développement (voir Développement psychologique)
Puberté
— Méthodologie d'étude 2.3.
— normale 3.4.
— , déroulement chez la fille 3.4.2.
— , déroulement chez le garçon 3.4.3.
Puberté
— précoce 7.3.7.
— retardée 7.3.6.
Pyle (voir Greulich et Pyle, méthode de)

Q

Quotient intellectuel 2.5.2.

R

Race 6.1.2.
Rachitisme 6.5.4.
Radiographie 2.2.3.
Rattrapage de la croissance 6.4.8.
Reins
— Insuffisance rénale 7.7.1.
— Maladies rénales 7.7.1.
Respiration 3.6.
— Affections, maladies respiratoires 8.6.
Retard de croissance et de puberté 7.3.

Risque, enfant à 8.3.
Royaume-Uni 9.6.12.

S

Saison 6.4.5.
Santé publique, indicateur en 1.2.5.
Scolaire, âge (voir Age scolaire)
Scolarité 5.4.
Séculaire, accélération 6.4.7.
Segments 3.1.2.
Sempé, méthode de 2.4.4.
Sénégal 9.3.2.
Sensoriel, développement 3.8.
Socio-économiques, conditions 6.4.1.
Somatotype 2.2.3.
Somatomédine (voir Hormone de croissance)
Sommeil 4.6.1.
Sport 6.4.6.
Standard
— Croissance 1.3
— , établissement, utilisation 2.2.2.
— Maturation dentaire 3.3.
— Maturation osseuse 3.3.
Statistiques 2.7.2.
Suède 9.6.13.
Suisse 9.6.14.
Surface corporelle 3.2.6.
Surrénales 7.6.3.
Syndromes complexes 7.4.3.

T

Taille 3.1.1.
— Excès chez la fille 7.3.2.
— Excès chez le garçon 7.3.3.
— Insuffisance chez la fille 7.3.4.
— Insuffisance chez le garçon 7.3.5.
— Prédiction 3.9.1.
— Relation poids/taille 3.2.2.
Tanner et Whitehouse, méthode de 2.4.3.
Tchécoslovaquie 9.6.15.
Tests
— mentaux 2.5.2.
— de Personnalité 2.5.3.
Tête, développement 3.5.
Thérapeutique
— endocrinienne 7.6.7.
— Hormone de croissance 7.6.2.3.
Thorax, développement 3.6.
Thyroïde 7.6.5.
Tissu adipeux 3.2.3.
Travail maternel 6.4.2.2.
Trisomie 21 7.5.3.
Tunisie 9.4.2.
Turner, syndrome de 7.5.1.
Turquie 9.4.3.

U

U.R.S.S. 9.6.16.
U.S.A. 9.1.1.

V

Venezuela 9.2.6.
Vitesse de croissance 3.1.4.
Volume du corps 3.2.6.

W

Whitehouse (voir Tanner et Whitehouse, méthode de)

Z

Zambie 9.3.3.

ALPHABETICAL INDEX BY SUBJECTS*

A

Accident 8.4.
Adipose tissue 3.2.3.
Adolescent
— Attitude 4.7.1.
— Bone maturation 3.3.6.
— Development and special problems 5.5.
— Puberty, delayed 7.3.6.
—, normal 3.4.
—, precocious 7.3.7.
Adoption 6.4.2.3.
Adrenals 7.6.3.
Africa
— Black 9.3.
— North 9.4.
Age group studies 5.
Allergy 8.7.
America
— Latin 9.2.
— North 9.1.
Animal, experimental studies 2.9.
Anoxia, fetus 7.8.4.
Apparatus 2.2.3.
Argentina 9.2.1.
Arm circumference 3.1.3.
Asia 9.5.
Attitude 4.7.
— Adolescent 4.7.1.

B

Behaviour 4.6.
Belgium 9.6.2.
Birth characteristics 5.1.
Birth weight 5.1.
Body
— Composition 3.2.5.
— Surface 3.2.6.
— Volume 3.2.6.
Bone
— Maturation 2.4.5., 3.3.
— Structural anomalies 3.3.8.

* The numbers refer to the references of the "plan of index" and not to the number of the publications.

— Thickness growth 3.3.7.
Boy
— Height
— , excess 7.3.3.
— , inadequate 7.3.5.
— Puberty 3.4.3, 5.5.
— , delayed 7.3.7.
— , precocious 7.3.6.
Brain development 3.5.
Breast-feeding 6.5.2.
Bulgaria 9.6.3.

C

Canada 9.1.2.
Cardiac disease 7.7.2.
Caribbean 9.2.
Catch-up growth 6.4.8.
Chest circumference 3.6.
Child caring arrangements 6.4.2.2.
Chile 9.2.2.
Chromosomal aberration 7.5.
Circumference
— Arm 3.1.3.
— Skull 3.5.
— Thorax 3.6.
Climate 6.4.5.
Computerized data 2.7.3.
Cuba 9.2.3.
Cystic fibrosis 7.6.8.
Czechoslovakia 9.6.15.

D

Data, recording and processing 2.7.4.
— Computerized 2.7.3.
Delayed growth and puberty 7.3.
Dental caries 8.8.
Dental maturation 2.4.6., 3.3.9.
Development
— Data: use in public health 1.2.5.
— Environment 6.3.2.
— Ethnic factors 6.1.2.
— Factors in — 6.
— Genetic factors 6.13.
— at Various periods 5.
— Physical 1.2.1, 1.2.2, 1.3.
— and Psychologic development, relations 4.9.
— Methodology of study 2.1.1.1.
— Psychologic and psychomotor development 4.
— and Environment 6.3.3.
— and Physical development, relations 4.9.
— Methodology of longitudinal study 2.1.1.2.
— Methodology of studies 2.5.
—, Sensory 3.8.
—, Sexual
— Methodology of study 2.3.
Diabetes 7.7.5.
Diameters 3.1.3.
Disease and growth 7.
Divorce 6.4.2.4.
Down syndrome 7.5.3.

E

Endocrine 7.6.
Enuresis 4.6.2.
Environment 6.3., 6.4.
— Climate 6.4.5.
— Cultural 6.4.3.
— Emotional factors 6.4.2.
— Family 6.4.2.
— and Physical growth 6.3.2.
— and Psychologic development 6.3.3.
— Socio economic factors 6.4.1.
Equipment 2.2.3.
Ethnic factors 6.1.2.
Europe 9.6.
Exchange transfusion 7.8.3.
Experimental study 2.9.
Eye, color 3.7.

F

Face, development 3.5.
Factors in development 6.
Family
— Broken homes 6.4.2.4.
— Environment 6.4.2.
— Intrafamilial factors 6.2.
Fat mass 3.2.3
Finland 9.6.5.
Fetal anoxia 7.8.4.
Fetal hypotrophy 7.8.2.
France 9.6.6.

G

Games 4.6.3.
Gastrointestinal disease 7.7.4.
Genetics
— Chromosomal aberration 7.5.
— Factors in psychologic development 6.1.3.
Germany 9.6.1.
Girls
— Height, excess 7.3.2.
— inadequate 7.3.4.
— Puberty 3.4.2., 5.5.
— delayed 7.3.6.
— precocious 7.3.7.
Gonads 7.6.4.
Greulich and Pyle, method of 2.4.2.
Growth
— Bone thickness growth 3.3.7.
— Catch-up growth 6.4.8.
— Delayed growth 7.3.
— Environment and physical growth 6.3.2.
— General 1.2.1.
— Height 3.1.
— Longitudinal studies 2.1.1.
— Mathematical formulation 2.7.1.
— Methodology of studies 2.
— and Nutrition 6.5.
— and Pathology 7.
— Precocious 7.3.
— Secular growth acceleration 6.4.7.
— Standards 1.3.
— Setting up and use 2.2.2.
— Subnormal 7.2.
— Velocity 3.1.4.
— Weight growth 3.2.
Growth hormone
— Deficiency 7.6.2.1.
— Effects 7.6.2.2.

— Levels 7.6.2.2.
— In Therapy 6.7.2.3.
Guidance 8.5.

H

Hair, color 3.7.
Handicap 8.5..
Head, circumference 3.5.
—, development 3.5.
Health indicator 1.2.5.
Heart disease 7.7.2.
Height 3.1.1.
— Excess, girl 7.3.2.
— , boy 7.3.3.
— Inadequate, girl, 7.3.4.
— , boy 7.3.5.
— Prediction 3.9.1.
— Ratio height to weight 3.2.2.
Heredity 6.1.
Hermaphroditism 7.5.4.
Housing 6.4.4.
Hungary 9.6.7.
Hypophysis 7.6.2.
— Insufficiency 7.6.2.1.
Hypopituitarism 7.6.2.1.
Hypotrophy, fetus 7.8.2.

I

Inborn error of metabolism 7.7.3.
Infant
— Bone maturation 3.3.4.
— Development and special problems 5.2.
— Mortality 8.1.
Intelligence, measurements of 2.5.2.
(see also Psychologic and psychomotor development)
— , quotient 2.5.2.
International comparative study 1.2.3.
Israel 9.4.1.
Italy 9.6.8.

J

Jamaica 9.2.4.
Japan 9.5.1.

K

Kidney 7.7.1.
— Renal insufficiency 7.7.1.
Klinefelter syndrome 7.5.2.

L

Language 4.4.
Latin America 9.2.
Longitudinal study, methodology 2.1.1.
— Psychologic 2.1.1.2.
— Somatic 2.1.1.1.
Lungs 3.6.

M

Malnutrition 6.5.3.
Maternal work 6.4.2.2.
Mathematical formulation 2.7.1.
Maturation
— Bone 3.3.
— , Methodology of study 2.4.5.
Maturation
— Dental 3.3.9.
— , Methodology of study 2.4.6.
— Sexual
— , Methodology of study 2.3. (see also Puberty)
Measurements, somatic measures
— Methodology, of study 2.2.
Menarche 3.4.2.
— Prediction 3.9.3.
Metabolic disease, inherited 7.7.3.
Methodology
— Bone maturation 2.4.
— Dental maturation 2.4.6.
— Growth study 2.
— Psychologic development 2.5.
— Sexual maturation 2.3.
Mexico 9.2.5.
Middle East 9.4.
Morbidity 8.
Mortality, infant 8.1.
Multiple births 2.8.

N

Nation growth study 1.2.2.
Netherlands 9.6.10.
Newborn 5.1.
— Perinatal anomalies 7.8.
North America 9.1.
Norway 9.6.9.
Nutrition and growth 6.5.

O

Obesity 3.2.4.
Orthopedic anomalies 7.4.
Ossification 3.3.7.

P

Parathyroid 7.6.6.
Parenteral feeding 7.7.4.
Pathology and growth 7.
Perinatal anomalies 7.8.
— Birth characteristics 5.1.
Personality
— Development 4.5.
— Prediction 4.8.
— Test 2.5.3.
Photography 2.2.3.
Physical activity 6.4.6.
Physical development (see Development, physical)
Pigmentation 3.7.
Pituitary 7.6.2.
— Insufficiency 7.6.2.1.
Play 4.6.3.
Poland 9.6.11
Population findings, observations 1.2.2., 1.2.3., 3.3.2., 3.3.3.
Prediction
— Height 3.9.1.
— Intelligence 4.8.
— Menarche 3.9.3.
— Personality 4.8.
— Weight 3.9.2.

Pregnancy 5.1.
Premature, prematurity 7.8.1.
Preschool age 5.3.
— Bone maturation 3.3.5.
Pseudohypoparathyroïdism 7.6.6.
Puberty
— Delayed 7.3.6.
— Methodology of study 2.3.
— Normal 3.4.
— , in girl 3.4.2.
— , in boy 3.4.3.
— Precocious 7.3.7.
Public health, indicator 1.2.5.
Pyle (see Greulich and Pyle method)

R

Race 6.1.2.
Radiography 2.2.3.
Reading 4.4.
Recording of data 2.7.4.
Renal disease, chronic 7.7.1.
Research, lines of 1.2.4.
Respiratory function 3.6.
— — illness 8.6.
Rickets 6.5.4.
Risk, children at 8.3.
Rural areas, compared with urban areas 6.4.4.

S

Schoolage 5.4.
— Bone maturation 3.3.6.
School attendance 5.4.
Season 6.4.5.
Secular growth acceleration 6.4.7.
Segments 3.1.2.
Sempé method 2.4.4.
Senegal 9.3.2.
Sensory development 3.8.
Skinfolds 3.2.3.
Skull, measurement 3.5.
Sleep 4.6.1.
Small-for-date 7.8.2.
Social classification 2.6.
Socio-economic factors 6.4.1.
Somatomedin, see Growth hormone
Somatotype 2.2.3.
Spain 9.6.4.
Speech 4.4.
Sport 6.4.6.
Standard
— Bone maturation 3.3.2.
— Dental maturation 3.3.2.
— Growth 1.3.
— Setting up and use of 2.2.2.
Statistics 2.7.2.
Subnormal growth 7.2.
Surface, body 3.2.6.
Sweden 9.6.13.
Switzerland 9.6.14.
Syndromes 7.4.3.

T

Tanner - Whitehouse method 2.4.3.
Tests
— Intelligence 2.5.2.
— Personality 2.5.3.
Therapy
Endocrinotherapy 7.6.7.
— Growth hormone 7.6.2.3.
Thorax, development 3.6.
Thyroid, 7.6.5.
Toilet training 4.6.2.
Tooth
— Decay 8.8.
— Maturation 3.3.9.
— Methodology of study 2.4.6.
Trisomy 21 7.5.3.
Tunisia 9.4.2.
Turkey 9.4.3.
Turner syndrome 7.5.1.
Twin studies 2.8.

U

Uganda 9.3.1.
Undernutrition 6.5.3.
United Kingdom 9.6.12.
Urban areas, compared with rural areas 6.4.4.
USA 9.1.1.
USSR 9.6.16

V

Velocity, growth 3.1.4.
Venezuela 9.2.6.
Volume, body 3.2.6.

W

Walking, age of onset 4.3.
Weight 3.2.1.
— Prediction 3.9.2.
— Ratio weight to height 3.2.2.
Whitehouse (see Tanner-Whitehouse method)
Working mother 6.4.2,2.

Z

Zambia 9.3.3.

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Imprimerie Corbaz S.A., Montreux Imprimé en Suisse